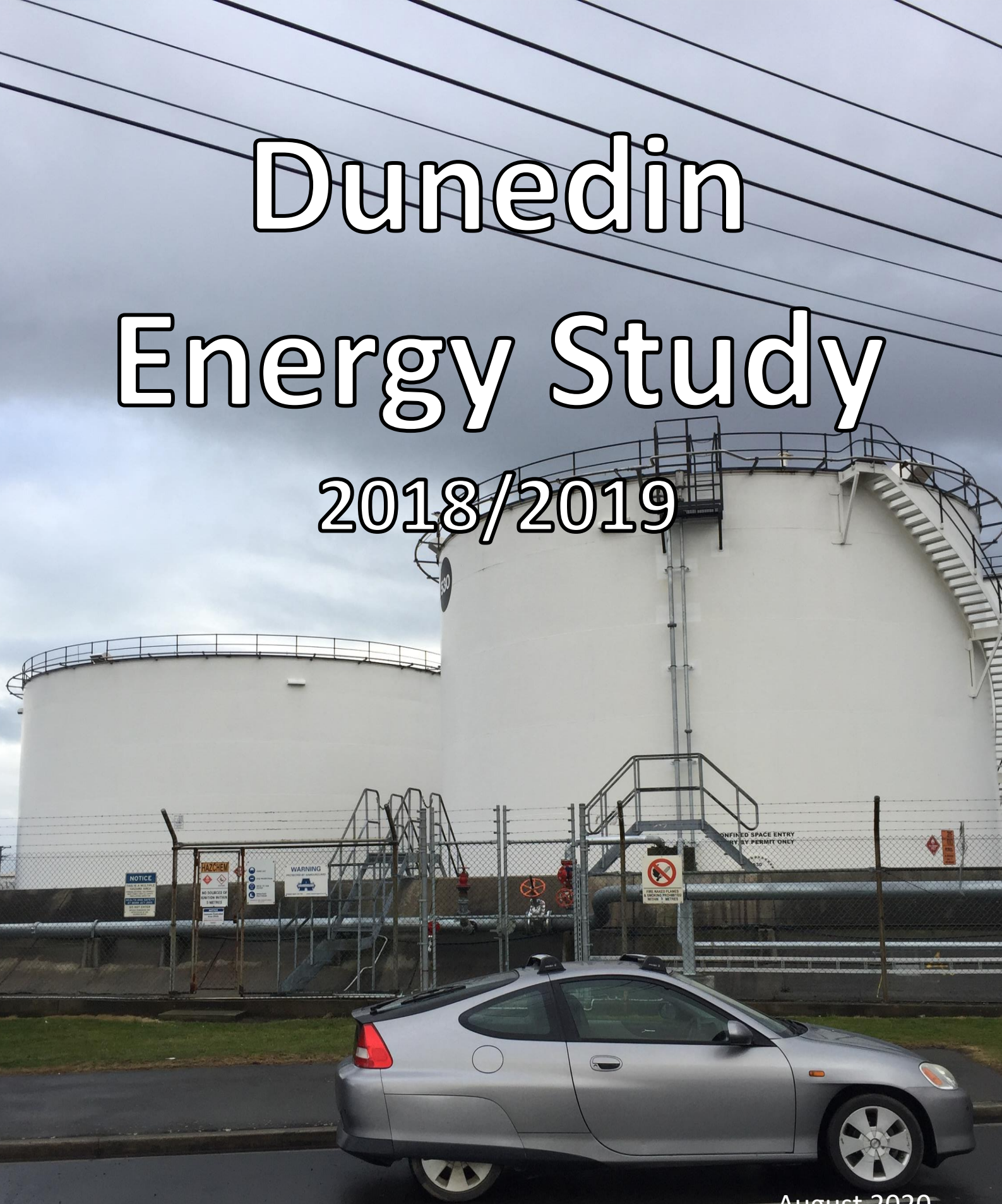
# Dunedin Energy Study

## 2018/2019

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Centre for Sustainability

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND
SAPERE AUDE

*Prepared for:*

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# Executive summary

## Summary of energy inputs

**A total of 13.72 PJ of energy was consumed in Dunedin during the 2019FY. This is a 2.3% increase from the 2018FY.**

Diesel is the single largest energy source consumed in Dunedin, making up 36% of all energy use within the city. This is followed by electricity (23%), petrol (20%), biomass (13%), coal (4%), LPG (3%) and sulphur (2%). These energy inputs are summarised in Figure 1.

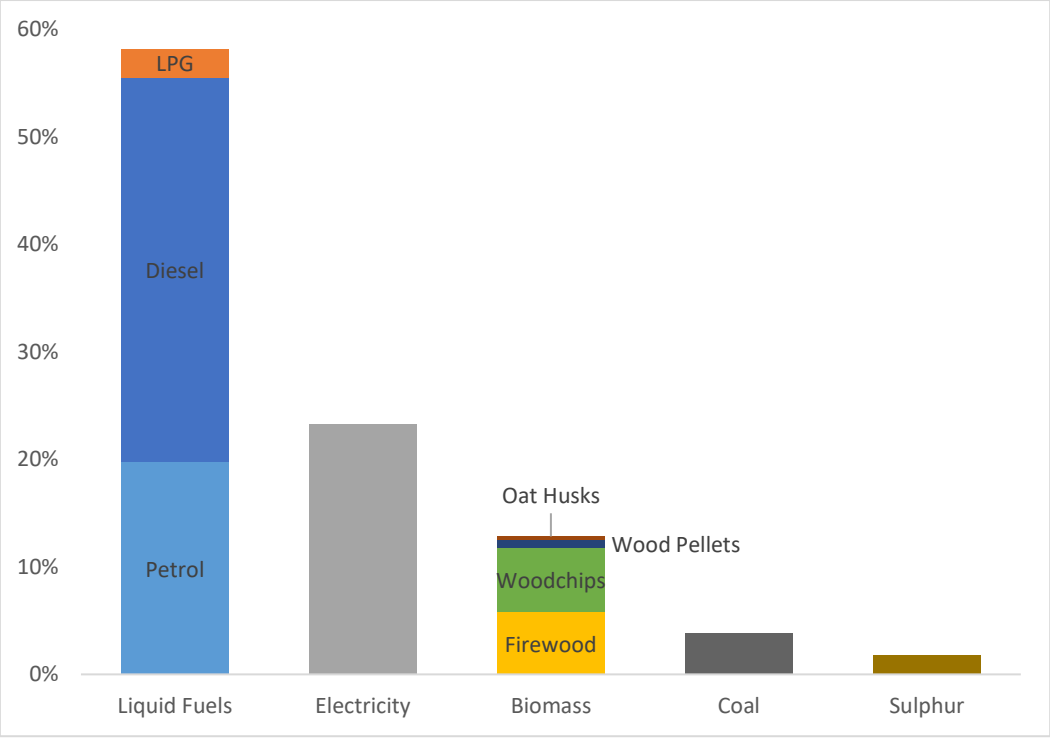


*Figure 1: Energy consumption profile for Dunedin city during the 2019FY*

## Sources of energy

A total of 84% of the energy used in Dunedin during the 2019FY was sourced from outside the city boundaries. All petrol, diesel, LPG, coal and sulphur are imported into Dunedin from other regions in New Zealand or from overseas. The majority of Dunedin's electricity use (82%) is derived from the national grid, and nearly all wood pellets were imported from Taupō based processors.

Locally sourced energy inputs are entirely made up of renewable energy sources in the form of biomass (92% locally sourced) and electricity (18% locally sourced). During the

2019FY, 0.582 PJ of electricity was produced from locally embedded generators. It is assumed that firewood (self-collected and retail) is sourced from within the city boundaries. Approximately 0.79 PJ of firewood was consumed in Dunedin in the 2019FY.

**Overall, 16% of the total energy used in Dunedin during the 2019FY was locally sourced. This comprised of 12% from biomass (mainly firewood and wood chips) and 4% from locally embedded electricity generation.**

It should be noted that Waipori (hydro) and Mahinerangi (wind) power schemes are located outside the city limits but are considered 'local' as the generated electricity is fed directly into the Dunedin electricity network.

## Renewable sources of energy

Around 33% of Dunedin's total energy consumption was from renewable sources, which is one percentage point higher than the previous year. The renewable portion is comprised of 20% from renewable electricity and 13% from biomass. In comparison, approximately 40% of energy consumed nationally in 2018 was from renewable sources[1].

During the 2019FY, around 86.9% of electricity supplied to Dunedin was generated from renewable resources. For the purpose of this study, all biomass (predominately wood) fuels are also considered renewable.

## Greenhouse gas emissions

During the 2019FY, approximately 695.67 kt $CO_2$-e (kilotonnes of $CO_2$-equivalent greenhouse gas emissions) was attributed to energy use in Dunedin. 77% of these emissions are attributed to liquid fossil fuel (petrol, diesel and LPG) consumption, 13% was attributed to electricity use in the city, 6% to coal use and 1% to biomass (mainly wood products).

Total $CO_2$-e emissions were up 2.7% from the 2018FY. This was predominately driven by the 6.5% increase in combined petrol and diesel consumption over the same period.

[1] Data sourced from MBIE, Energy balances: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-balances/

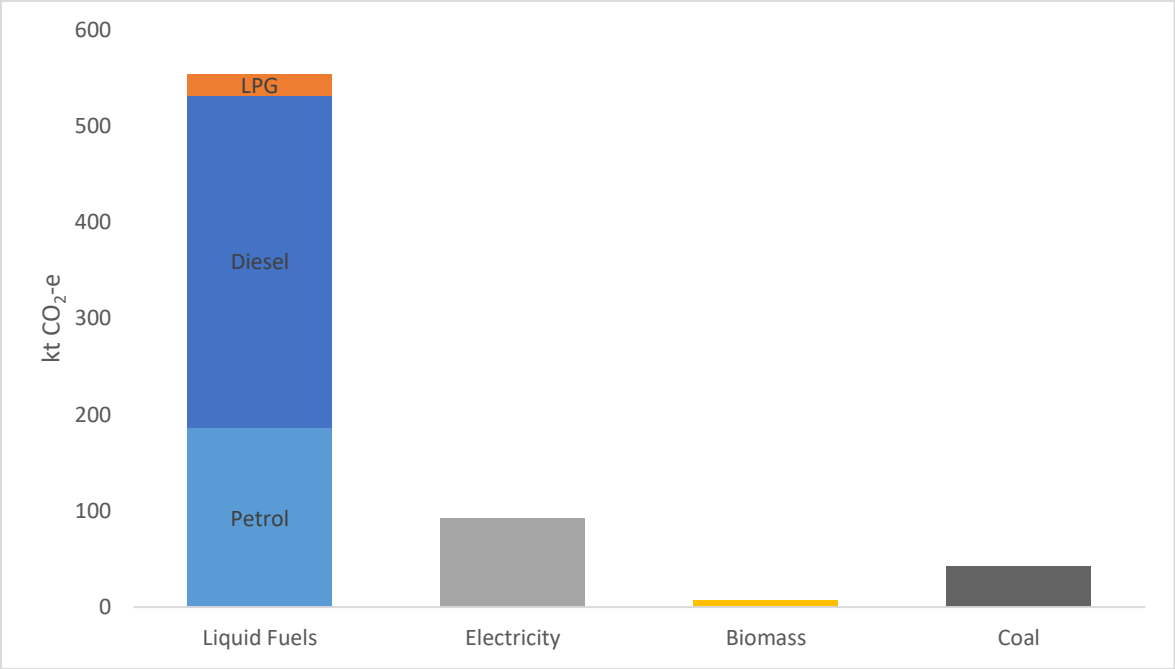


*Figure 2: Greenhouse gas emissions associated with Dunedin's energy consumption during the 2019FY.*

## Key trends 2016-2019

Worryingly, Dunedin's key energy trends over 2016-2019[2] are heading in the opposite direction from the city's goals:

- Dunedin's annual energy consumption has increased from 11.61PJ to 13.65PJ, a **17.6% increase, or an average of nearly 4.5% per year**.
- Energy consumption per capita has increased from 25.39 MWh to 28.79 MWh per capita, **a 13% increase, or an average of 3.25% per year.**
- Energy consumption per unit of GDP has increased from 570MWh to 615 MWh per $million GDP, **a 7.9% increase** (i.e. energy use has become less efficient), or an **average of nearly 2% per year**.
- There has been an increase in the **proportion of non-renewable fuels** in the energy supply from **63% to 67%**.
- **Energy-related greenhouse gas** emissions have increased **15.7%,** an average increase of **nearly 4% per year**.

See section 9 for more details on trends.

[2] As reported for the 2015-16 financial year in the second Energy Study; the 2016-17 financial year in the third Energy Study; the 2017-18 financial year in the fourth Energy Study, and the 2018-19 financial year in this study.

# 1. Background

The Dunedin Energy Study is a joint research project between the Dunedin City Council (DCC) and the Centre for Sustainability at the University of Otago. The study takes stock of, and analyses energy inputs into the city of Dunedin.

This annual study is an action under the DCC's Energy Plan 1.0, which recognises the need to encourage research that will enable the monitoring of Dunedin's energy uses and inputs over time. It will also help inform and assist with implementing other Energy Plan 1.0's actions, such as the Electric Vehicles action (promoting EV uptake and supporting infrastructure development) and Biomass action (expanding the production and use of biomass energy).

This study was conducted between November 2019 and May 2020 and provides an estimation of the total amount of each energy type used within the city, along with an indication of the end uses of energy, and energy-related greenhouse gas emissions.

The project relied entirely on the willingness of many businesses and organisations who supplied data. The project's partners are extremely grateful to all participating individuals and organisations who dedicated a considerable amount of time to sourcing, compiling and providing relevant data.

## About Dunedin

In this study, "Dunedin" refers to the area under jurisdiction of the Dunedin City Council (DCC), which is surrounded by Waitaki District in the north, Central Otago District in the west, Clutha District in the south and the Pacific Ocean in the east (Figure 3).

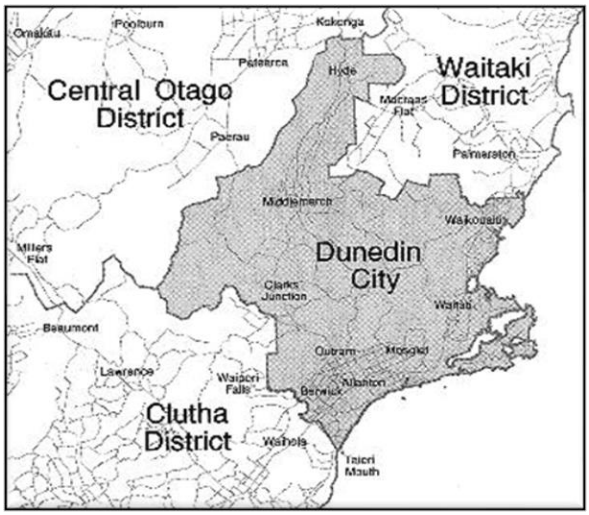


*Figure 3: Dunedin City Boundaries*

## Population

Dunedin had an estimated[3] population in 2019 of around 131,700 people, an increase of 0.9% over the previous year.

Dunedin's population represents 2.68% of New Zealand's total population[4] and is the second largest city in the South Island, the largest in the Otago Region and the 7th largest in size of the 67 districts in New Zealand.

In terms of employment, the three largest industries in Dunedin during 2019 were Health Care and Social Assistance (14.9%), Education and Training (13.5%), and Retail Trade (10.1%). The industries that experienced the greatest increase in employment numbers from the previous year, were Education and Training (509), Healthcare and Social Assistance (317), Heavy and Civil Engineering Construction (256). The industry which experienced the greatest reduction in employment was Food Production Manufacturing which lost 292 jobs from 2018[5].

## Economy

Dunedin had a gross domestic product (GDP) of $6.162 billion for the 2019 financial year. This is up 3.2% on the previous and is greater than the national growth rate of 3.0% over the same period.

Among broad industries Health Care and Social Assistance was the largest in Dunedin City in 2018 accounting for 9.7% of total GDP. This was followed by Education and Training (9.4%), and Construction (8.2%).

# About the Dunedin Energy Study

This is the fifth consecutive year this study has been run and investigates energy consumption within Dunedin during the 2019 financial year (2019FY), referring to the financial year period 1 July 2018 – 30 June 2019. The first Dunedin Energy Baseline Study investigated the 2014 calendar year; the second Energy Study investigated the 2015 calendar year and the 2015-16 financial year; the third Energy Study investigated the 2016-17 financial year; and the fourth Energy Study investigated the 2017-2018

[3] Source: http://nzdotstat.stats.govt.nz/wbos/index.aspx
[4] Source: http://nzdotstat.stats.govt.nz/wbos/index.aspx
[5] Dunedin City Annual Economic Profile 2019 (https://ecoprofile.infometrics.co.nz/Dunedin%2bCity/PDFProfile#h8)

financial year. The shift to financial years had a better fit with the way our project partners gather their data.

The Dunedin Energy Study focuses on end use energy within Dunedin, as well as energy imported into Dunedin and energy produced/generated in Dunedin. The study looks at direct energy consumption only, not energy embedded in goods and services.

The primary aim of the current Dunedin Energy Study is to build on previous studies to start to expose energy use trends. Further refinements to data collection and analysis have been made to help improve some of the data gaps from previous reports. The main improvements in the current report relate to the imports of LPG and quantities of biomass consumed within Dunedin.

Data is presented for the 2019 financial year (2019FY - 1 July 2018 to 31 June 2019).

Much of the data collated in this report was not publicly available and relied on the participation and willingness of the businesses and organisations who supplied it. Where available, more in-depth data is presented to show temporal and spatial patterns of energy use.

The Energy End Use Database, held by the Energy Efficiency and Conservation Authority (EECA), has been used to provide a comparison between the values presented in this study and national averages. The EECA database used for this comparison has estimates for national energy use for the 2016 calendar year[6], but no longer appears to have data specific to the Otago Region. Data from previous reports has therefore been used to compare against the Otago region in 2012. A comparison between the findings of this report and those from the Energy End Use Database is included in the National Comparisons (Section 8 of this report).

Research was undertaken by researchers at the University of Otago. Ethical approval was granted for the research project. Individuals and organisations participating in the study were given options regarding the anonymity and confidentiality of the data provided. Where requested, anonymity has been preserved by aggregating the energy inputs by fuel type. The raw data collected is securely stored at the University of Otago and is only available to the study's primary investigators.

[6] EECA released an updated Energy End Use Database in Sept 2020, too late to be included in this report.

## Conversion Factors

Energy data was originally gathered in the units used in that sector. To enable comparisons, all were converted to the common unit of petajoules (PJ). 1 PJ is equivalent to 1,000,000,000 MJ. Conversion factors based on net calorific values were used to convert fuel quantities from the originally reported units as follows:

| Energy Form | Conversion[7] | Density[8] |
|---|---|---|
| Electricity | 3.6 MJ/kWh | N/A |
| Petrol | 35.08 MJ/L | 0.73 kg/L |
| Diesel | 38.45 MJ/L | 0.83 kg/L |
| LPG | 26.44 MJ/L | 0.53 kg/L |
| Coal | 24.303 MJ/kg | |
| Firewood | 9.63 MJ/kg | 556 kg/$m^3$ |
| Wood pellets | 17.17 MJ/kg | 640 kg/$m^3$ |
| Wood chips | 9.63 MJ/kg | 736 kg/$m^3$ |

These conversion rates are consistent with previous studies.

## Comparability to previous Dunedin Energy Studies

In 2014 the Dunedin Energy Baseline Study was completed. The baseline study was the first attempt to capture energy sources supplied to Dunedin. This fifth consecutive Dunedin Energy Study has further refined the data collection and analysis methodology developed in the previous studies. This study can be compared to the 2016FY, 2017FY and 2018FY results, but it should be noted that some methodological changes have been made in this study. These changes are detailed in the relevant sections, and where

[7] Statistics New Zealand "New Zealand Energy Use: Services sector 2013" (http://www.stats.govt.nz/browse_for_stats/industry_sectors/Energy/EnergyUseSurvey_HOTP13/Data%20Quality.aspx#energy); EECA Business "Biomass calorific value calculator" (https://www.eecabusiness.govt.nz/tools/wood-energy-calculators/biomass-calorific-value-calculator/); MfE Guidance for Voluntary Greenhouse Gas Reporting – 2016 (http://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/2016-guidance-for-voluntary-corporate-greenhouse-gas-reporting.pdf)

[8] New Zealand Centre for Advanced Engineering "New Zealand Energy Information Handbook" (https://ir.canterbury.ac.nz/bitstream/handle/10092/11527/EIH3.pdf?sequence=1)

applicable, results from previous years have been updated to be comparable with the current methodologies used in this study.

The main methodological updates to the current study are:

- Use of updated Census data from 2018 to calculate various fuel consumption amounts
- Increased quality of biomass data collected and analysed
- Improved methodology for electricity consumption calculation

# 2. Liquid fossil fuels

## Methods and Assumptions

Liquid fuels used in Dunedin include petrol, diesel and liquefied petroleum gas (LPG). These fossil fuels are imported from outside the DCC area.

In this section, petrol and diesel are presented separately from LPG.

## 2.1 Petrol and diesel

### Petrol and diesel supply in Dunedin

Petrol and diesel are imported into Dunedin through Port Otago. There are ten companies that sell petrol and diesel in significant quantities in Dunedin: BP NZ LTD, Chevron CALTEX, Exxon MOBIL, Z Energy, McKeown & Graham, Allied Petroleum, CRT Farmlands Fuel, RD Petroleum Ltd, GULL NZ Ltd and Nelson Petroleum Distributors (NPD).

The data on Dunedin's petrol and diesel supplies were compiled using tax data collected by DCC. DCC collects a Local Authorities Fuel Tax under the Local Government Act 1974, whereby all quantities of these fuels sold (that comply with the Act) need to be disclosed and tax files returned. This includes fuel that is distributed through retail and wholesale outlets, but does not include fuel used to generate electricity, aviation fuel, LPG, or fuels used for commercial shipping.

The data is collected by DCC for the Tax Area of Coastal Otago, and includes both the quantities of petrol and diesel sold and the corresponding tax payable. The Tax Area of Coastal Otago includes geographical regions outside the jurisdiction of DCC (and therefore outside the study area). The area was defined in 1971 as Dunedin City; Oamaru, Port Chalmers, St. Kilda, Green Island, Mosgiel, Balclutha, Kaitangata and Milton Boroughs; and Waitaki, Waikouaiti, Waihemo, Taieri, Bruce and Clutha Counties. Of these areas, Oamaru and Waihemo lie to the north of Dunedin in what is now Waitaki District, and Balclutha, Kaitangata and Milton Boroughs, and Clutha County lie to the south in what is now Clutha District.

DCC uses the comparative percentage of rates incomes in the portions of the three territorial authorities (Dunedin City, Waitaki District and Clutha District) that lie within the defined Coastal Otago Tax Area to allocate tax revenue. In the 2019FY the Dunedin

City percentage was 70.44%. This has been applied to the petrol and diesel tax data to estimate the share of these fuels used in Dunedin.

This study has adopted the 'percentage of rates income' method so as to be consistent with DCC's strategy for allocation of the fuel taxes. This is consistent with previous Dunedin Energy Studies. It does not reflect the actual consumption of these fuels but is as close an approximation as can be achieved based on currently available data.

Prior to 1 July 2015, the DCC fuel tax data was not separated by fuel type, so the average proportion of 40% petrol and 60% diesel from 2016FY data was applied to estimate fuel quantities for the 2015 financial year.

Figure 4 shows the annual totals of petrol and diesel consumption in Dunedin from 2015FY to 2019FY. The included trend line shows that both petrol and diesel use is increasing in Dunedin. Although there has been an increase in diesel supply of 12.1% from 2018, there has been a decrease in petrol supply of 2.3%.

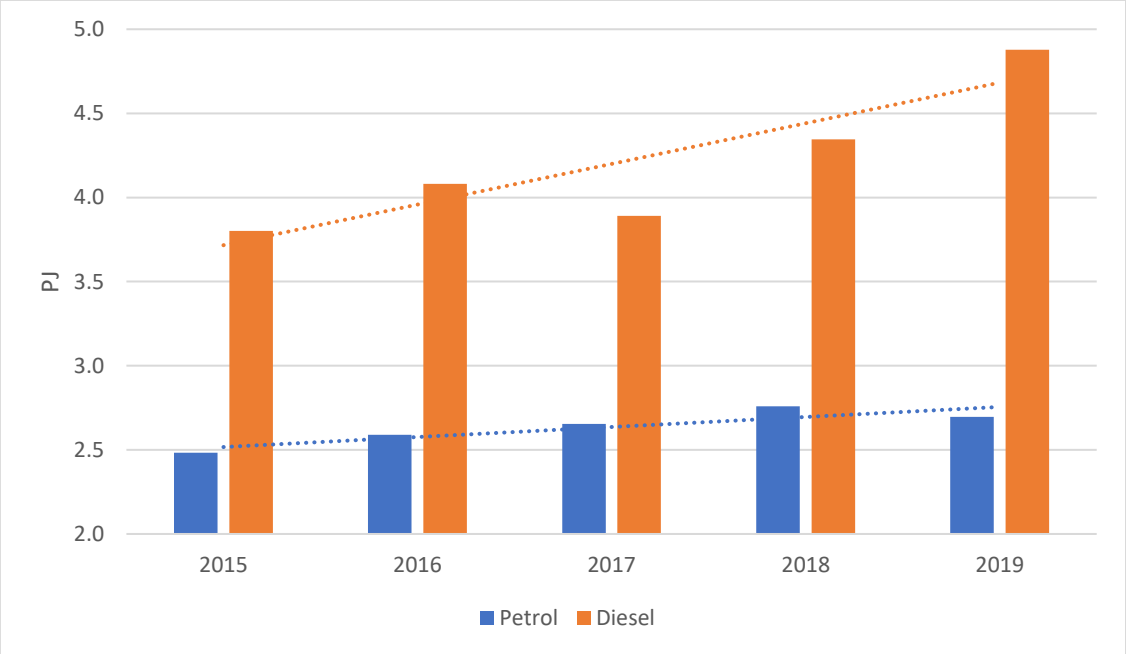


*Figure 4: Annual petrol and diesel energy use in Dunedin.*

Fuels used to generate electricity are not subject to the DCC tax levy and therefore not included in the above figures. Fuels used for generation have been estimated in the fuel demand section below.

Comparing the total amount of petrol and diesel sold in Dunedin with that imported via Port Otago, it is apparent that the other regions outside of Dunedin also source their

fuels through Port Otago. It is estimated that approximately 39.8% of the amount of petrol and diesel imported through Port Otago was consumed within Dunedin.

## Petrol and diesel consumption in Dunedin

Nationally, diesel use increased in 2019, with the biggest increases being in the agricultural, fishing, forestry, commercial and public services[9]. Based on the tax data and rating apportionment method described above, Dunedin has also seen a significant increase in diesel use.

Although data is not available as to where diesel and petrol are being used in Dunedin, it is likely that the majority of petrol and much of the diesel is used for transport. Other uses include in agriculture, forestry, fishing, home and commercial heating, industrial uses and in generators. Further research on diesel end-use is advised in order to understand what is driving the increase in demand.

As of March 2020, there were 107,969 vehicles registered to Dunedin owners – this includes both heavy and light vehicles, and includes all company vehicles. Heavy vehicles and those with a high duty-cycle tend to be diesel powered, such as trucks and buses. This is an increase of 3,404 vehicles from March 2019. 78% of these vehicles are petrol powered and 21% are diesel powered. The remainder is made up of 67 LPG vehicles (see section 2.1) and 799 electric vehicles (see section 3), the latter making up 0.74% of the vehicle fleet.

An approximation has been made to account for the transboundary use of transport fuels. Some of the petrol and diesel purchased in Dunedin service stations will be used in vehicles that drive beyond the city, and some vehicles coming into the city will have purchased their petrol and diesel elsewhere. For the purposes of this study it has been assumed that these quantities would be similar and therefore cancel each other out.

During periods of high electricity demand, local network companies can request large users to reduce their consumption. University of Otago and the Southern District Health Board consumed a total of 0.0003 PJ of diesel to run their generators during the 2019FY. We don't have equivalent data for other major organisations with generators. However, assuming all large electricity users within Dunedin have a similar capacity to generate electricity during peak periods, is has been estimated that an additional 0.010 PJ of

[9] https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/oil-statistics/

diesel could have been consumed for electricity generation during the 2019FY, which represents a very small proportion (0.1%) of total fuel use.

**A total 7.58 PJ of fuel, comprised of 2.70 PJ of petrol and 4.89 PJ of diesel, was consumed within Dunedin during the 2019FY. This represents a 12.1% increase on the total diesel consumed in Dunedin compared to 2018FY, and a 2.3% decrease in total petrol consumed. This is a remarkably similar change to the 2018FY which saw a 12.2% increase in diesel and 2% decrease in petrol.**

**Further research is needed to assess whether the tax data and rating apportionment method is a sufficiently accurate approach to assess petrol and diesel use, and what is driving the ongoing diesel increase.**

## 2.2 LPG

### LPG supply in Dunedin

There are four LPG wholesalers in Dunedin: Genesis, Contact (Rockgas – sold to First Gas in November 2018), Elgas and Ongas. This is distributed to customers either in bottles, tanks or on the local reticulated LPG network.

Most LPG arrives in Dunedin via coastal shipping from the Taranaki gas fields, although some is imported from Australia during winter/gas field outages. One wholesaler also receives LPG supplies via rail directly from the gas fields in Taranaki. LPG is imported into the city in large shipments and stored at a logistics handling company in Dunedin or in ISO containers. Import records will therefore show large monthly variations and will not always directly relate to LPG consumption. This is visible in Figure 7 where the 'demand' curve follows, but is smoother than, the 'imports' curve.

*Note: In the process of reviewing the LPG data, it was found that some of the historic data used in the Dunedin Energy Studies prior to 2017, based on a model of shipping vs rail, may have overpredicted the amount of LPG imported via rail. A model had been created to try and analyse the effect of the Kaikōura earthquake (14 Nov 2016) on LPG imports by rail. All LPG was temporarily transported via coastal shipping until an alternative source could be obtained. Data has since been obtained from KiwiRail about the amount of LPG unloaded in Dunedin since the railway lines have been repaired and this has been used to update our historic modelled estimates. This has been considered when analysing past data and has been used to improve estimates of the volumes of LPG transported by each method. Note this correction only affects pre 2017 reports as complete data has been obtained for the previous three years.*

Figure 5 shows a divergence between the modelled (predicted) and actual maritime LPG imports between November 2016 and September 2017. This aligns perfectly with the period that the railway infrastructure was out of service due to the Kaikōura earthquake.

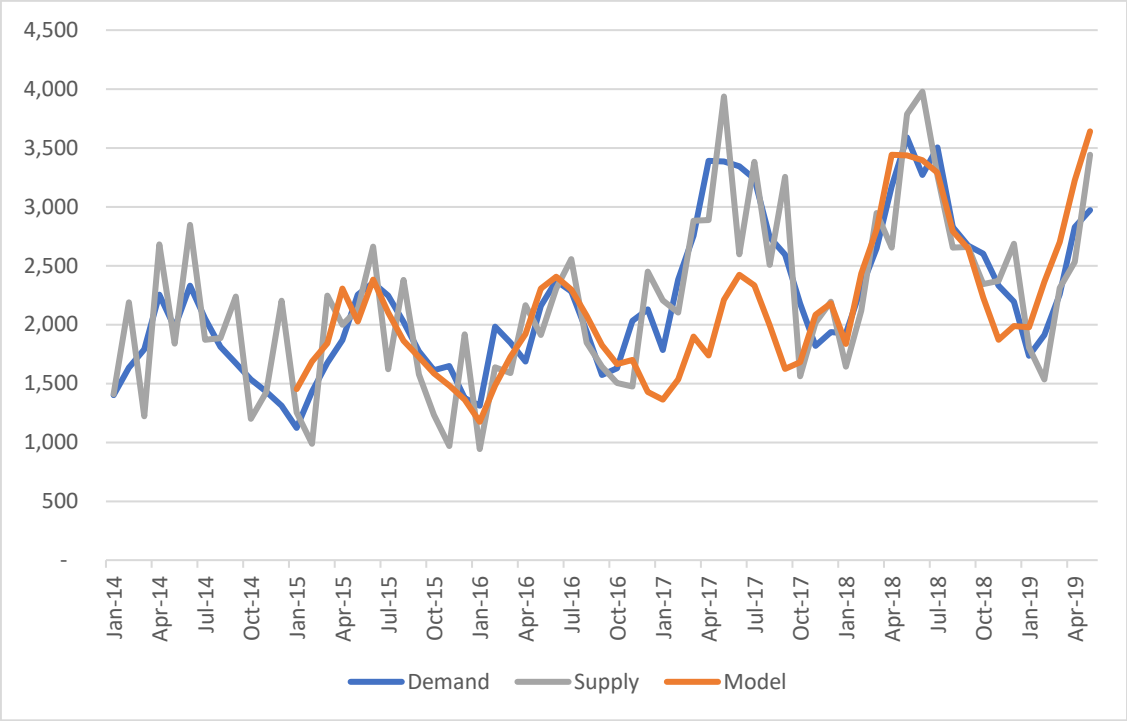


*Figure 5. Modelled (orange) and actual (grey) maritime imports of LPG into Dunedin (units removed for confidentiality)*

As far as can be established from discussions with retailers, LPG imported into Dunedin is distributed all around the southern half of the South Island[10]. We have adopted the assumption that this is in proportion to population, which results in 40% allocation for Dunedin. **However further research is needed to identify the locations of major users of LGP as this assumption could be incorrect.**

[10] The areas supplied roughly correspond to the districts of Dunedin City; Clutha, Central Otago, Queenstown Lakes (202,467); Southland, Invercargill City, Gore (93,339) and roughly half of Westland (i.e. 4,153). The total population supplied was therefore estimated to be 299,959. Dunedin's population of 120,249 amounts to 40% of this total. All values are based on 2018 census data to provide accurate relative populations.

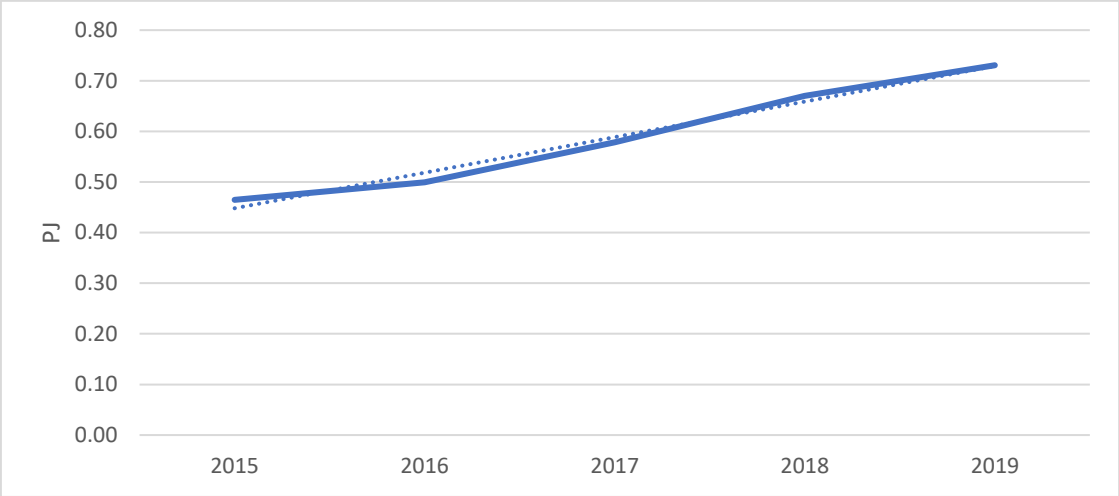


Figure 6. *Estimated annual supplies of LPG to Dunedin*

Although caution should be taken with this data because of the uncertainty with the allocation method, Figure 6 shows an ongoing increase in the amount of LPG supplied in Dunedin since the Dunedin Energy Study began.

**A total of 0.731 PJ of LPG is estimated to have been supplied to Dunedin during the 2018FY. Based on updated values, this represents an increase of approximately 9.1% from the 2018FY.**

## LPG consumption in Dunedin

LPG is used in Dunedin for multiple purposes including industrial applications, residential use and transport.

Monthly data of LPG consumption and moving average data of imports has been used to analyse consumption patterns; this is currently the best representation of actual LPG usage for Dunedin.

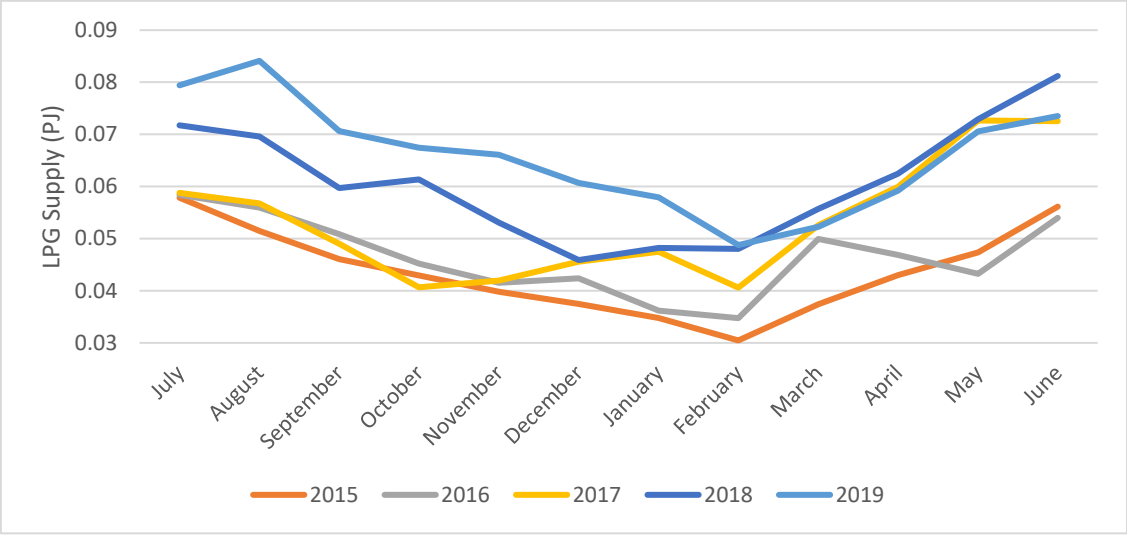


*Figure 7: Annual LPG supply trends*

Figure 7 shows the monthly trends of LPG supplied to Dunedin. Although the amount of LPG supply is increasing, the pattern of consumption is very consistent between years and shows an increase in consumption over winter months as LPG is a common heating fuel source in the city. The variation between years is less obvious and may require several more years of data to determine any long-term trends.

## Commercial LPG use in Dunedin

EECA has a Heat Plant Database that contains public information about boilers in New Zealand, including those using LPG[11]. A similar dataset was obtained from Ahika and the Bioenergy Association of New Zealand (BANZ). Both datasets were compiled and validated against actual consumption data from the University of Otago, Dunedin City Council and the Southern District Health Board.

**Commercial LPG demand was equivalent to 0.259 PJ during the 2019FY, an increase of 0.8% on the 2018FY.**

## Residential LPG use in Dunedin

Many households in Dunedin use LPG for water heating, space heating and cooking. There is currently no way of determining exactly how much LPG is used residentially and for what exact purpose the LPG is being used in the household. Approximations have been made based on previous census results, last updated in 2018.

[11] The EECA heat plant database was last reviewed in 2014 and there may be subsequent changes which have not been captured on this list.

A linear regression of census data from 2001, 2006, 2013 and 2018 was used to estimate that 2,759 Dunedin households used bottled or reticulated gas as a heating fuel in 2019FY.

The Home Heating Report[12] from 2005 estimates that households that use gas would use an average of 2kg of gas per day across both winter and non-winter months.

**Dunedin's residential LPG use was approximately 0.100 PJ in the 2019FY, an estimated reduction of 21% on the 2018FY.**

## LPG used for transport in Dunedin

LPG is also used as a transport fuel. In Dunedin, there are four petrol stations that sell LPG. These are Burnside Service station, Green Island; Complete Auto Repairs Ltd, Hillside Road; Caltex City North and Mobil Anzac Ave.

Data obtained from the New Zealand Transport Association (NZTA) reveals that as of March 2019 there are 67 LPG vehicles registered in Dunedin. This corresponds to approximately 804,000km[13] of travel by LPG vehicles. LPG vehicles use 10-20% more fuel than petrol vehicles and so an LPG consumption of 8.671 litres per 100 km has been assumed.

**Approximately 0.0018 PJ of LPG is used for transportation in Dunedin on an annual basis.**

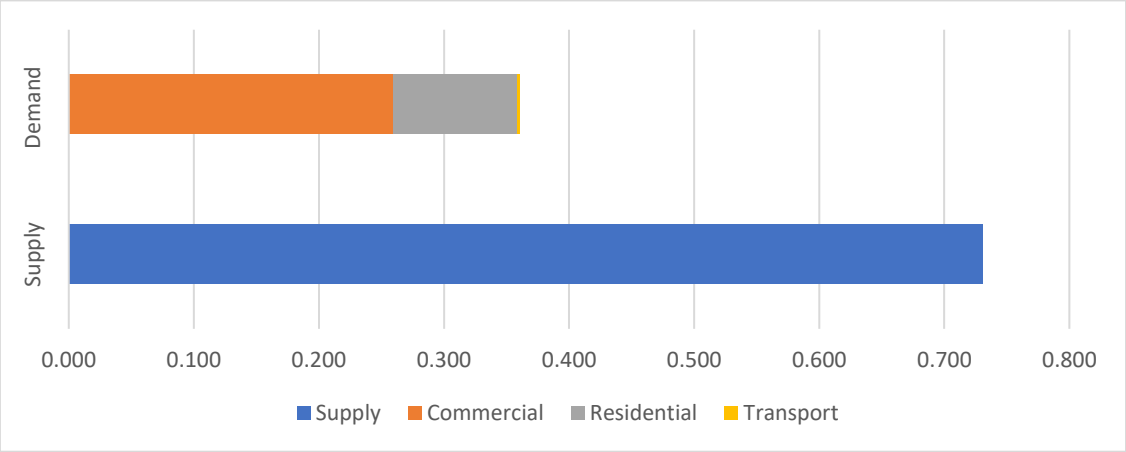


*Figure 8: Comparison of LPG supply and demand in Dunedin for the 2019FY*

[12] Source: Ministry for the Environment, 2005. Warm Homes Technical Report: Home Heating Methods and Fuels in New Zealand. (Prepared by Emily Wilton)

[13] Source: http://www.transport.govt.nz/assets/Uploads/Research/Documents/New-Zealand-Vehicle-fleet-stats-final-2013.pdf

In the 2019FY, only 49% of the assumed LPG supply is accounted for by the calculated demand for LPG in Dunedin. This is is a decrease on previous years (58%-72% based on updated figures), and it is obvious that additional work is required to improve the discrepency between suppy and demand. Accurate data for land and sea based imports of LPG are now known; it is therefore assumed that these discrepancies must be due to uncertainties in the proportion of LPG distributed from Dunedin to other areas, and/or poor data on LGP end-users in Dunedin.

**A total LPG demand of 0.361 PJ was calculated for Dunedin during the 2019FY. This represents a 6.4% reduction in LPG demand from 2018FY.**

**The discrepancy between calculated supply and demand represents one of the largest uncertianties in this report and requires further research.**

# 3. Electricity

## Methods and assumptions

The data on electricity used in Dunedin comes from the distribution companies, the energy advisory company Energy Link and the Electricity Authority database of installed capacity[14] of distributed generation.

There are two distribution companies that operate in Dunedin: Aurora and Otago PowerNet. Aurora operates in the urban and suburban areas of Dunedin whereas Otago PowerNet operates in the rural outskirts surrounding the Dunedin urban centre. Dunedin, which includes the settlements of Hyde, Middlemarch, Clarks Junction, Hindon, Waitati and Karitane, represents only a small portion of Otago PowerNet's territory.

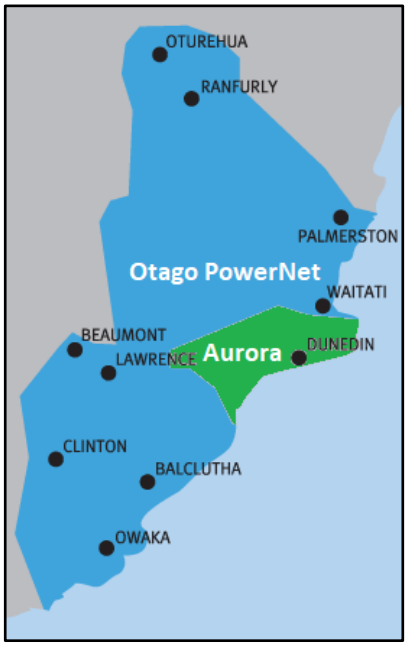


*Figure 9: Location of the Aurora network (green) and Otago PowerNet network (blue) in relation to Dunedin*

In Aurora's 2019 disclosure year[15] there were 55,361 ICPs[16] on their network, while PowerNet had a total of 3,065 ICPs in Dunedin as of March 2019[17]. The total number of ICPs has increased by approximately 0.6% since the 2019FY.

[14] Installed capacity is the maximum production capacity.
[15] Auroras reporting period is from 1st April to 31st March whereas the financial year for the rest of this report is 1st July to 31st June.
[16] An ICP is an individual connection point; this is the physical point of connection on a network at which a retailer will be deemed to supply electricity to a consumer. (Electricity Authority, 2016 - http://www.ea.govt.nz/glossary/)
[17] There is no monthly breakdown of ICPs on the PowerNet network.

## Electricity supply in Dunedin

**Dunedin was supplied with a total of 3.185 PJ of electricity during the 2019FY. This is an increase of 0.6% from the 2018FY.**

### Electricity supply from the national grid

During the 2019FY, Dunedin consumed 3.185 PJ of electricity. This was comprised of 2.603 PJ (82%) from the national grid and 0.582 PJ (18%) supplied by generation embedded in the local network.

Although Dunedin's electricity is largely generated from renewable South Island locations, it is integrated within the wider national grid where all demands and supplies are connected. If a certain demand was therefore removed from the system, the excess electricity would be used elsewhere within the network. For this reason, national averages have been used for the renewable proportion of electricity generation, as well as the subsequent emissions factors for this generation, regardless of whether it was generated locally or supplied by the national grid.

**84% of New Zealand's electricity generation was from renewable sources during the 2019FY. This is 2 percentage points higher than the 2018FY.**

### Local Generation

There are a variety of different electricity generators embedded within the Dunedin electricity network. Table 1 provides a summary of the known local generators and the energy sources they use.

To describe these locally embedded generators more fully, we have split them into three scales: large generators (over 50 MW); mid-scale generators (0.1 MW to 5 MW) and small-scale (less than 0.1 MW).

*Table 1: Local electricity generation in Dunedin for the 2017FY*

| | Name of connected generator | Generating company | Energy type | Total electricity supplied (MWh) | Total installed capacity (MW) |
|---|---|---|---|---|---|
| Large generators | Waipori 33kV – Deep Stream 1A, 2A | TrustPower Ltd | Hydro | 65,932 | 53 |
| | Waipori 33kV - Mahinerangi | TrustPower Ltd | Wind | 96,932 | 36 |
| Mid-scale generators | Ravensdown Generation | Ravensdown Ltd | Process Steam | 690 | 3 |
| | Container Port | Port Otago Ltd | Liquid Fuel | 19 | 1.6 |
| | Waste Water Treatment Plant | Dunedin City Council | Biomass | 20 | 1 |
| | Dunedin Airport | Dunedin International Airport Limited | Liquid Fuel | - | 0.6 |
| Small-scale generators | Various Distributed Generators | 384 Individual connections | Solar | 1,570[18] | 1.43 |
| | Various Distributed Generators | 7 Individual connections | Wind | 49.6[19] | 0.023 |
| Total | | | | **165,212** | **96.7** |

## Large generation schemes

There are two large generation schemes that supply Dunedin with electricity. These are the Waipori hydropower scheme and the Mahinerangi wind power scheme. These two systems work in synergy with each other, allowing water to be preserved while the wind farm is generating. Although both generation schemes lie outside of Dunedin, they feed directly into Dunedin's 33 kV network and have therefore been included in the local generation for Dunedin.

[18] Includes self-consumption. Solar calculations are based on assumption that the solar panels are north facing at are tilted at 45 degrees. The solar calculator at https://www.energywise.govt.nz/tools/solar-calculator/ was used to find a conversion rate of 1100kWh/kW a year.

[19] Includes self-consumption. Energywise assumes that small wind turbines generate at on 10 to 40% of their rated capacity every hour and so for this study it has been assumed that on average wind turbines operate at 25% capacity. Therefore, a conversion rate of 2190kWh/kW a year. https://www.energywise.govt.nz/at-home/generating-energy/small-wind-turbines/ - Energyoutputofsmallwindturbines

The Waipori hydropower scheme has total of four stations along the Waipori River with a combined installed capacity of 84 MW, plus an additional 5 MW of capacity at the Deep Stream hydro scheme. Only 53 MW of this is connected directly into Dunedin's Aurora network via a 33 kV transmission network from the Waipori 1A, 2A and Deep Stream generators to the Halfway Bush substation. Excess generation from the Waipori 2A, 3 and 4 generators, is fed into the national grid via a 110 kV transmission line to the Berwick substation located on the Taieri plains.

Stage 1 of the Mahinerangi wind farm was commissioned in 2011 and contains 12 turbines with a total installed capacity of 36 MW. These were tied into the 33 kV transmission network from Deep Stream and subsequently all 36 MW of capacity is fed into the Dunedin network via the Halfway Bush substation. Consent has been granted for an additional 160 MW of wind generation at the Mahinerangi site, although this would require upgrades to the transmission network.

The 33 kV Waipori transmission network is currently insufficient to support the full generating capacity of all the generators installed on it. The various generators are therefore operated in synergy with each other to allow hydro capacity to be stored while the Mahinerangi wind farm is generating, all while working within the limits of the transmission system. To balance out any excess generation, Waipori 2A is connected to both the local Dunedin network and the national grid so that no generating capacity is wasted.

In Aurora's April 2018 – March 2019 financial year Dunedin was supplied with 65,932 MWh (0.2374 PJ) of hydro-generated electricity from the Waipori/Deep Stream system and 96,932 MWh (0.3490 PJ) of wind-generated electricity from Mahinerangi. This is an 11% increase in hydro generation and a 9% increase in wind generation, resulting in an overall increase in local large scale generation of 10% from the 2018FY.

Data is presented in Figure 12 for electricity supplied into the local Dunedin network from the Waipori, Deep Stream and Mahinerangi generation schemes over the previous five disclosure years. Some variation is present in both the hydro and wind generated electricity which is supplied to Dunedin, however any long-term trends may be influenced by the transmission limits more so than the generation potential.

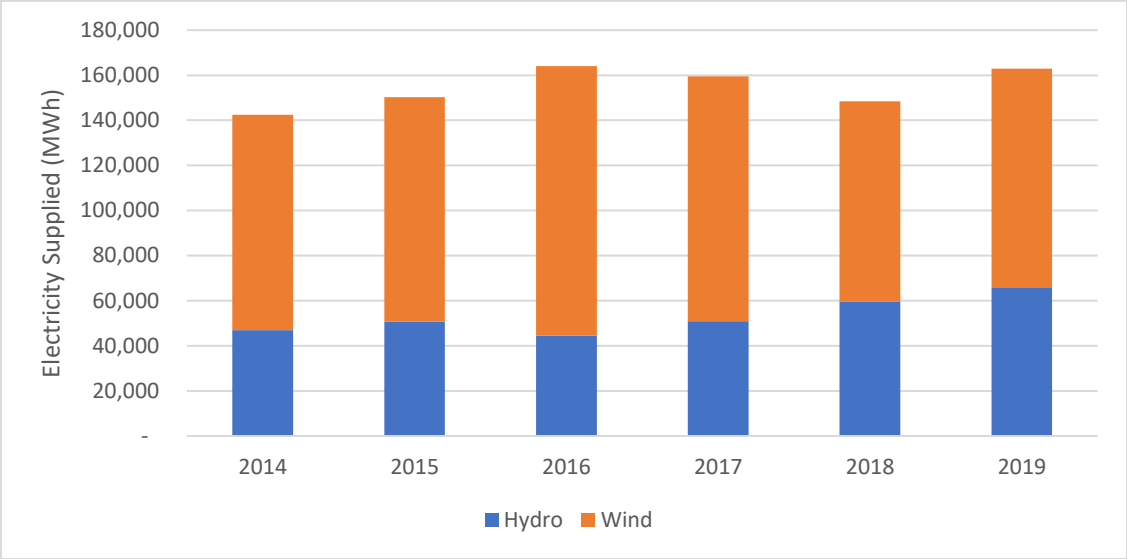


*Figure 10: Electricity supplied directly into Dunedin's local network from Waipori/Deep Stream (hydro) and Mahinerangi (wind) generators.*

## Mid-scale generation

Mid-scale local generators of electricity are those that have 0.1 MW to 5 MW in capacity. These include Ravensdown Ltd (from process steam), Port Otago's container port (from liquid fuels), and the DCC's waste treatment plant (from biogas). The Dunedin Airport also has 0.6 MW of synchronised generation capacity (from liquid fuels) but does not export any into the local network.

Biogas generation from the Green Island landfill and wastewater treatment plants have decreased to around 10MWh per year since 2016. The amount of mid-scale generation in Dunedin is therefore largely determined by the industrial processes at Ravensdown Ltd. This site generates electricity from process steam which is a by-product created during the production of fertiliser.

There was a 12% decrease in mid-scale generation from 813 MWh (0.0029 PJ) for the 2018FY, to 728 MWh (0.0026 PJ) for the 2019FY.

## Small-scale distributed generation

Small-scale generators of electricity are those that produce less than 0.1 MW.

As of the 30$^{th}$ of June 2019, there were 384 solar systems and seven wind turbines connected to the Dunedin electricity network. This is an additional 55 solar systems (+17%), resulting in a 27% increase in installed capacity, from the end of the 2018FY. The calculated electricity generation of these small-scale generators equates to 1,570 MWh (0.0057 PJ) from solar and 49.6 MWh (0.0002 PJ) from wind for the 2019FY.

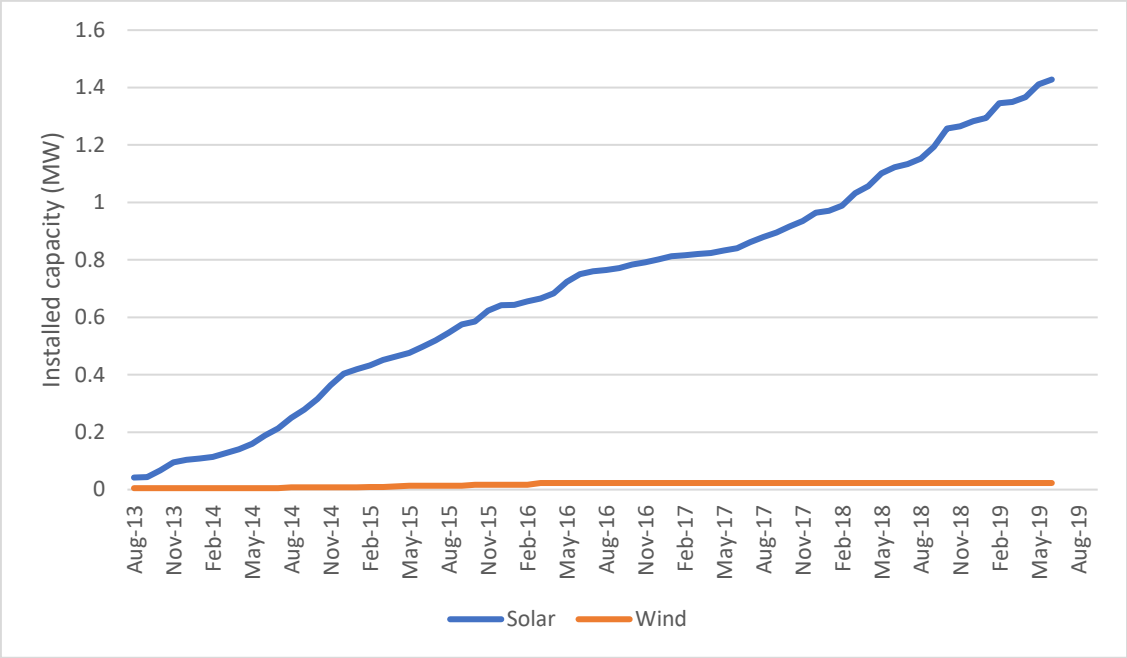


*Figure 11: Cumulative small-scale installed capacity on the local Dunedin network.*

Photovoltaic solar installations in Dunedin appear to be increasing at a roughly linear rate of an average of 62 connections per annum since 2013. The average size of the installed systems is increasing, consistent with national trends. The average capacity for new solar systems installed in Dunedin during the 2019FY was 5.4 kW, up from 3.7 kW during the 2018 FY.

There has been an increase in industrial solar installations. During the 2019FY, three industrial installations have increased the industrial share of solar distributed generation capacity from 1% to 5%.

Five new wind turbines were installed during the 2014 and 2015 calendar years. However, there have been no new wind installations connected to the grid since September 2015.

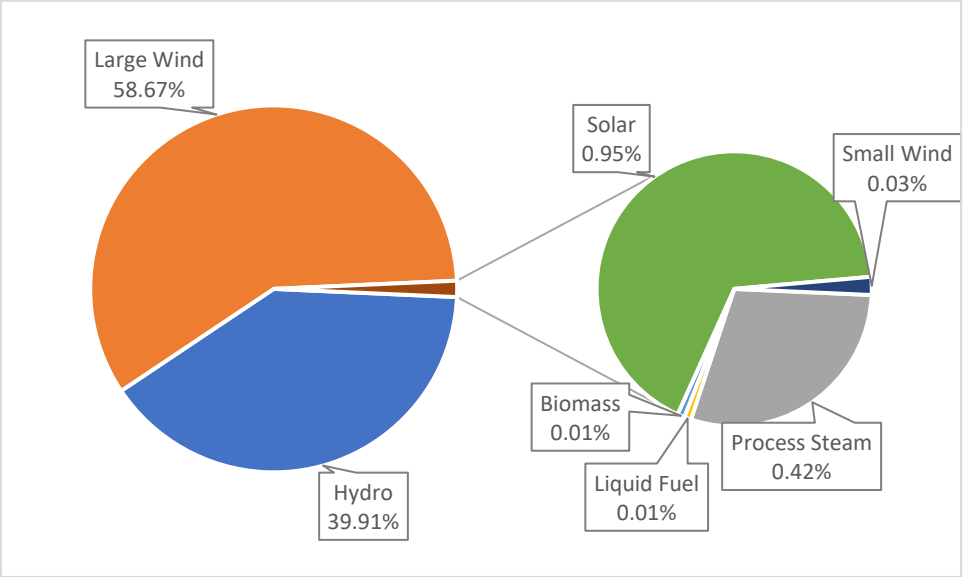


*Figure 12: Electricity generated within the Dunedin network during the 2019FY.*

Figure 12 shows the comparative production from locally embedded generators. The mid-scale and small-scale generators make up around 1.4% of the total local generation, with solar producing the majority of this.

### Network losses

Average network losses for the Aurora network during the 2019FY were 6%. Network losses are caused by heat generation in powerlines and transformers, and represents the difference between the amount of electricity which enters the local grid and that which is delivered to customers. All these values are similar to those during the 2018FY, with a slight increase in line loses (+0.1%) and residential consumption (+2%) during the 2019FY.

The Otago PowerNet network had 3,065 ICPs within Dunedin which consumed 30 GWh of electricity with average network losses of 7.5%.

## Electricity demand in Dunedin

During the 2019FY, 96.6% of Dunedin's electricity was supplied by Aurora. This network includes most of the urban areas of Dunedin and is served by the Halfway Bush and South Dunedin grid exit points. The remaining 3.4% of Dunedin's electricity was supplied by PowerNet, which mainly includes the rural areas within the city boundary and is served by the Halfway Bush and Naseby grid exit points. These relative proportions have not changed significantly (0.1% increase in Otago PowerNet share) from the 2018FY.

In the 2019FY, Aurora reported that 49% (393 GWh) of the electricity distributed on its network was consumed by 48,415 residential connection points; 50% (401 GWh) was consumed by the 6,942 non-domestic connection points and 1% (8 GWh) was used for street lighting.

The Electricity Authority's Electricity Market Information website[20] shows a breakdown of electricity connections by main centres. It is not known whether the 'main centre' of Dunedin on this site is the same as Dunedin City, but the breakdown by user type is at least indicative. The EMI for June 2019 shows 51,563 residential connections, 5855 small-medium enterprises, 5321 commercial connections and 1808 industrial connections.

From the same website, the graph below shows average residential consumption across New Zealand's main centres. It shows that Dunedin and Christchurch households use considerably more electricity than households in other centres.

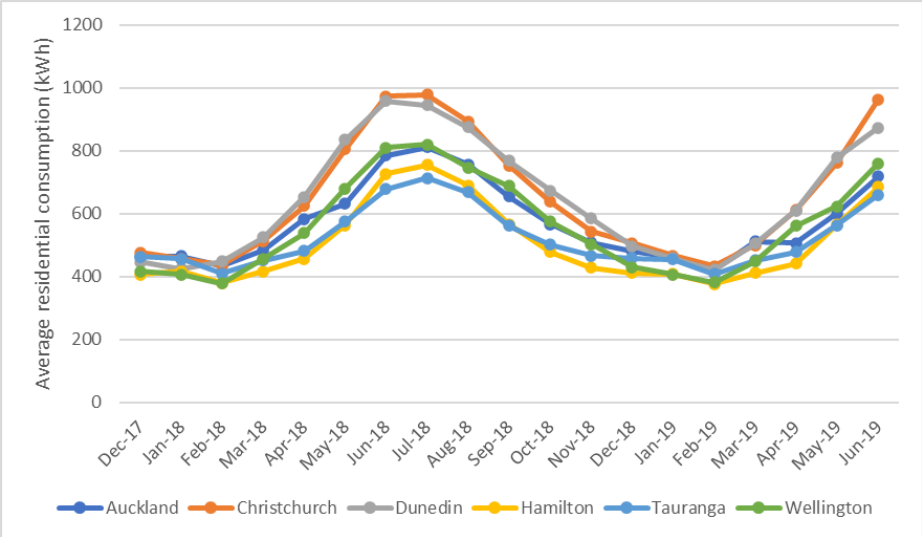


*Figure 13: Residential consumption trends 01 Dec 2017 - 30 Jun 2019: average residential consumption, main centres.*

## Electric vehicles

Electricity is also used for transportation in Dunedin. Dunedin had 799 electric vehicles (EVs) as of December 2019. The EV fleet in Dunedin has steadily increased every year

[20] Electricity Authority (2020) https://www.emi.ea.govt.nz/Retail/Reports/H3WIHL?_si=v|3,tg|market-structure

since 2015, with 308 new registrations in the 2019 calendar year.[21] Of these, 11% are company owned with the remaining 89% for personal use.

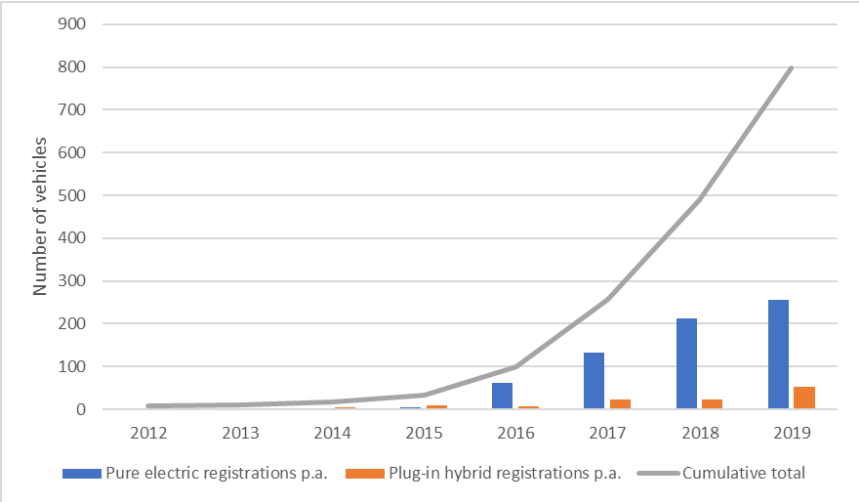


*Figure 14: Annual growth of electric vehicles in Dunedin to December 2019.*

Dunedin currently has the highest rate of electric vehicle ownership compared to other New Zealand cities. There are 5.16 battery electric vehicles (e.g. Nissan Leaf, Tesla Model S) per 1000 residents, well ahead of the next rival Wellington (4.39). Adding in plug-in hybrid electric vehicles (e.g. Mitsubishi Outlander, Toyota Prius), Dunedin was still slightly ahead of Wellington (6.07 and 6.01 per 1000 residents respectively), and well ahead of other main cities.

Dunedin also has the highest proportion of electric vehicles registered for personal use (5.38 per 1000 residents), well ahead of Wellington (4.39) and Christchurch (4.19).

[21] Ministry of Transport, Monthly electric and hybrid light vehicle tables: https://www.transport.govt.nz/mot-resources/vehicle-fleet-statistics/monthly-electric-and-hybrid-light-vehicle-registrations-2/

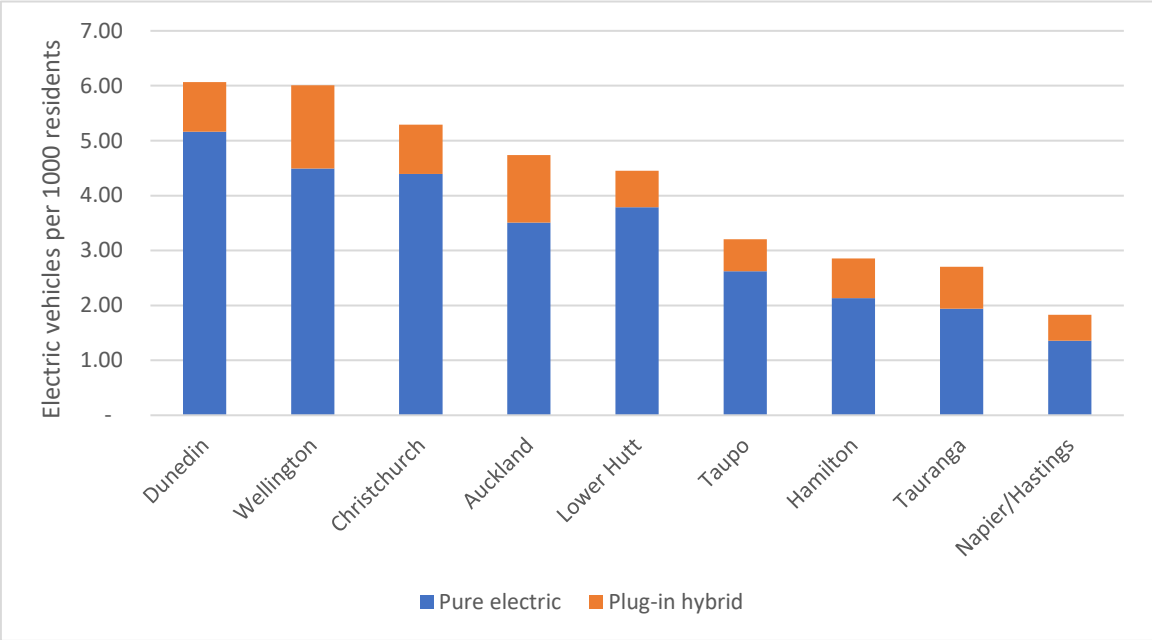


*Figure 15: Electric vehicles per 1000 residents by type for main New Zealand cities as at the end of 2019.*

Dunedin's EV uptake characteristics are further explored in a separate report available for download.[22]

[22] Stephenson, J., & Cook, F. (2020). Electric vehicle uptake in Dunedin 2019 (Technical Report). Retrieved from http://hdl.handle.net/10523/10043

# 4. Biomass

There are three main categories of wood that are used in Dunedin: wood pellets, woodchips and firewood. These three wood fuels are used in different ways with woodchips primarily being used for industrial boilers, whereas wood pellets and logs (i.e. firewood) are used in both boilers and residential heating.

Wood fuels are sold in multiple retail outlets, as well as direct commercial contracts with forestry owners and self-collection of firewood. The extremely varied nature in which wood fuels enter, and are used, in Dunedin make them very difficult to quantify.

Discrepancies were found in the previously reported values of most wood fuels. These have been corrected and updated in the current study but mean that results may not be directly comparable to previous studies. Where applicable, comparisons have been made with the updated values from previous years.

Uncertainties arise from the distributed nature of both the supply and demand of wood fuels, however the values calculated in this study are comparable for both supply and demand, and therefore provide a relatively high confidence in the results.

## 4.1 Wood pellets

### Wood pellet supply in Dunedin

Wood pellets are supplied from a variety of retailers and industrial suppliers around the city.

These pellets are imported into the city from manufacturers in Taupō (Nature's Flame) and Nelson (AzWood) as well as smaller manufacturers from Timaru, Tapanui and Invercargill.

Due to the distributed nature of wood pellet imports, it is difficult to determine the exact quantity supplied to consumers within Dunedin. Personal communications with several industry representatives however, suggests that annual residential pellet supply is around 2,400 tonnes (0.040 PJ), and annual industrial pellet supply is around 12,000 tonnes (0.206 PJ).

**Dunedin was supplied with approximately 0.246 PJ of wood pellets during the 2019FY. This is an increase of approximately 2.2% since the 2018 FY.**

# Wood pellet demand in Dunedin

## Organisational wood pellet demand

Information was compiled from personal communications, the EECA boiler list and data provided by Ahika and BANZ to establish a database of commercial boilers in Dunedin. This database was used to estimate the total installed capacity and fuel demand for different boiler fuel types within Dunedin. There are eight known wood pellet boilers used at educational facilities within the city. This includes two new pellet boilers which were installed in Dunedin schools during the 2018FY. These all have a rating of between 400 kW and 1460 kW.

During the 2018FY, Otago University underwent a move towards more sustainable fuels and increased its consumption of wood pellets from 0.002 PJ during the 2017FY to 0.01 PJ in the 2018FY. This has decreased to 0.007 PJ in the 2019FY.

**It is estimated that 0.0553 PJ of wood pellets was used in organisational boilers within the city during the 2019FY. This is a decrease of around 5.9% since the 2018FY.**

## Residential wood pellet demand

There are two main installers of pellet fires in Dunedin; Otago Pellet Fires and The Dunedin Fireplace. Comprehensive pellet fire data was not available from all installers, but at least 498 new pellet fires were installed during 2019 which brings the total number of recorded pellet fires in Dunedin up to 2261.

**It is estimated that 0.0395 PJ of wood pellets were used by Dunedin residents during the 2019FY.**

**Across both organisational and residential demand, a total of 0.095 PJ of wood pellets were consumed in Dunedin during the 2019FY. This is an increase of 1.8% from the 2019FY, which is predominantly due to the increased consumption of wood pellets by Dunedin residents.**

# 4.2 Woodchips

## Woodchip supply in Dunedin

Wenita and City Forests are the two main forestry owners and suppliers of wood fuels in the Dunedin area (Figure 15). These two firms provide logs for firewood and woodchips to wholesalers or directly to customers. Wholesalers may sell these wood products directly or pass them on to one of the many retailers of firewood in Dunedin. A 50/50 split was assumed between woodchips and firewood where more accurate records were not available.

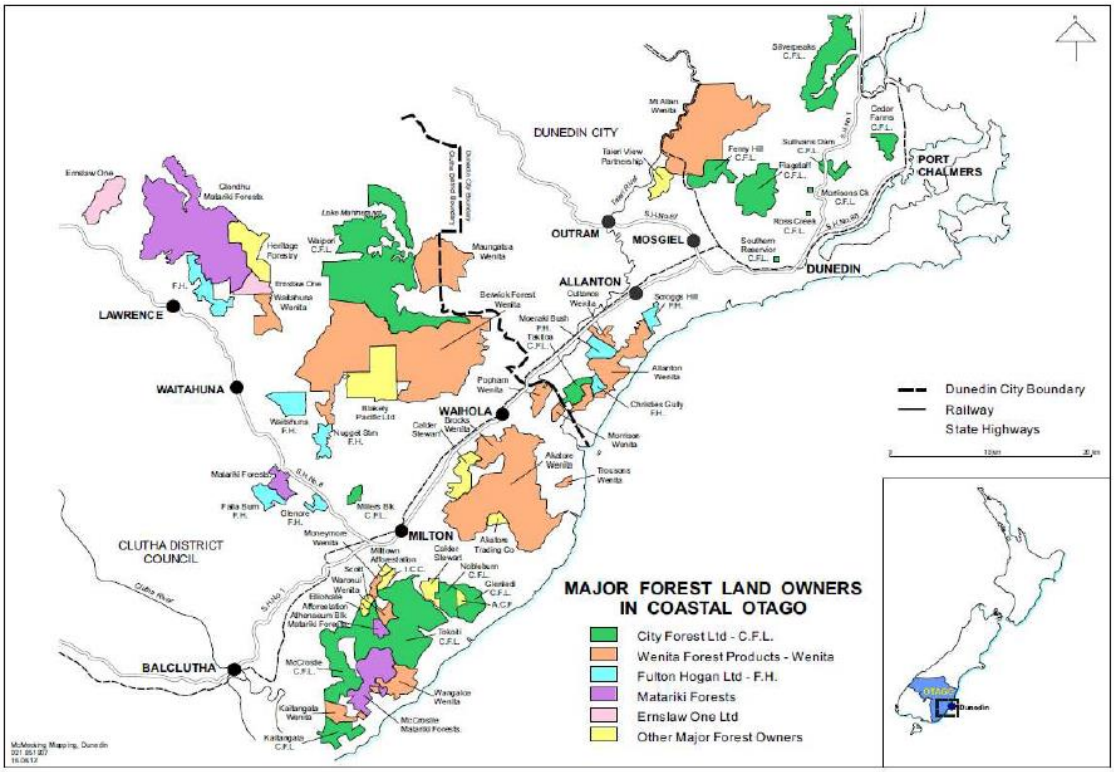


*Figure 16: Major forest land owners in Coastal Otago.*

**Based on data supplied by Wenita and City Forests, it is estimated that at least 0.133 PJ of woodchips were supplied to Dunedin during the 2019FY. This is an increase of 87% on the 2018FY.**

### Woodchip demand in Dunedin

#### Organisational demand

Several data sources were used to calculate the woodchip energy consumed in organisational boilers within Dunedin. Where available, direct energy consumption data was used to improve the accuracy of this study. Data was also derived from the EECA boiler list, Ahika and BANZ, which identified 11 other boilers in Dunedin that use woodchips as their primary fuel type. During the 2019FY it is estimated that 0.799 PJ of woodchips were consumed in these boilers.

The Dunedin Energy Centre which historically combusts coal for steam generation converted of one of its four coal boilers to run on woodchip fuel. This was completed during September 2018 and since becoming operational has consumed 0.067 PJ of woodchips.

The University of Otago and the Southern District Health Board also use woodchips in a number of their own boilers. During the 2019FY, the university and affiliated residential colleges consumed 0.011 PJ of woodchips and the hospitals consumed 0.014 PJ of woodchips.

**Overall, 0.892 PJ of woodchips were consumed in organisational boilers within Dunedin during the 2019FY. This is an 8.4% increase from 2018FY and is likely to be primarily driven by the boiler conversion at the Dunedin Energy Centre.**

## 4.3 Oat husks

### Oat husk demand in Dunedin

Combined data from the EECA boiler list, Ahika and BANZ, has identified two boilers that use oat husks as a fuel source. These boilers are located at Harraway & Sons Ltd and are fuelled by the waste husks from their own processing line.

**During the 2019FY, it is estimated that 0.043 PJ of oat husks were consumed in these two boilers.**

# 4.4 Firewood

## Firewood supply in Dunedin

Commercial firewood supplies are largely met by the two local forestry companies, Wenita and City Forests (Figure 15). These two firms provide logs for firewood to several of the main retailers in Dunedin.

**In the 2019FY there was 0.085 PJ of logs sold for firewood by forestry owners in Dunedin. This is 13.4% less than the previous financial year.**

## Residential firewood demand

Data from the 2018 Census shows that 43.7% of Dunedin households report using a woodburner as one of their main heating methods. This equates to 21,249 households. A linear regression of census data from 2001, 2006, 2013, and 2018 was used to predict that approximately 21,582 Dunedin households used firewood as a heating fuel in the 2019FY.

Firewood can either be purchased or obtained from private sources. Data on self-collected firewood is harder to obtain as it is not recorded anywhere. A survey that the Ministry for the Environment[23] carried out in 2005 concluded that over 60% of wood used in solid fuel burners and 40% of wood used in multi-fuel burners was self-collected.

In 2016, a 'People's Panel' survey was created through the DCC and collected data from 349 Dunedin residents. The results showed that of those who used firewood[24], 58% obtained it through non-retail channels and 42% bought it from a retailer. The results of this survey correlate well with the 2005 findings from the Ministry for the Environment.

The People's Panel survey showed that on average, each household that used firewood would consume 7.17 cubic metres per year. This includes households that only use firewood for heating and those that use firewood and other fuels for heating purposes.

**It is estimated that Dunedin residents consumed 0.789PJ (147,400 $m^3$) of firewood (including purchased and self-collected wood) in the 2019FY. This is 1.1% less than the 2018FY.**

[23] Source: Ministry for Environment, 2005. Warm Homes Technical Report: Home Heating Methods and Fuels in New Zealand.
[24] 221 out of the 349 respondents to the Peoples Panel survey used firewood in 2016.

# Total wood fuels

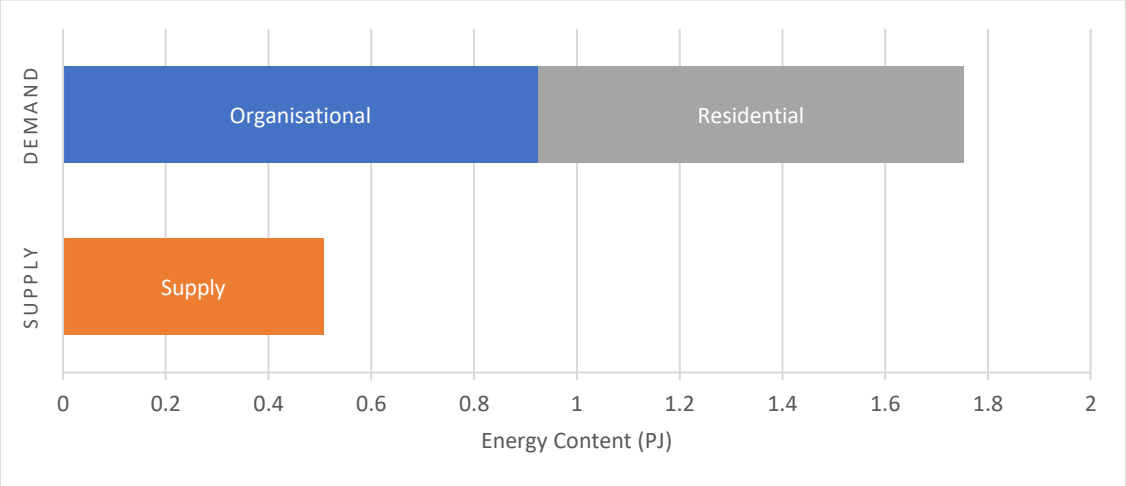


*Figure 17: Comparison of calculated organisational and residential wood fuel demand and supply in Dunedin during the 2019FY.*

Figure 17 shows the ratio of organisational wood fuel use to residential wood fuel use in Dunedin.

During the 2019FY, 53% of wood fuels were used by large organisational boilers and 47% of wood fuels were used by residential households. As seen, there is a large disparity between the calculated supply and demand. Previous studies show a better match but in this study we detected a methodological error in past calculations that overestimated the supply of woodchip and firewood supplies. This has been rectified in this study.

***Further work is needed to investigate the gap between calculated demand and calculated supply.***

*Figure 18: Wood fuel use by type during the 2019FY in Dunedin.*

Figure 18 shows the breakdown of wood fuel use by type in Dunedin. During the 2018FY, 45% of wood fuels were firewood, 47% were woodchips, 5% were wood pellets and the remaining 2% were oat husks used by a local food processor.

The calorific values for wood fuels have been updated from previous reports so these findings cannot be directly compared to previous Dunedin Energy Studies.

Figure 19 provides an annual comparison in wood fuel use over the past four years, with historic values updated to the current calorific value and methodology. This shows that there have been only minor variations in the amount and type of wood fuels consumed in Dunedin since 2015.

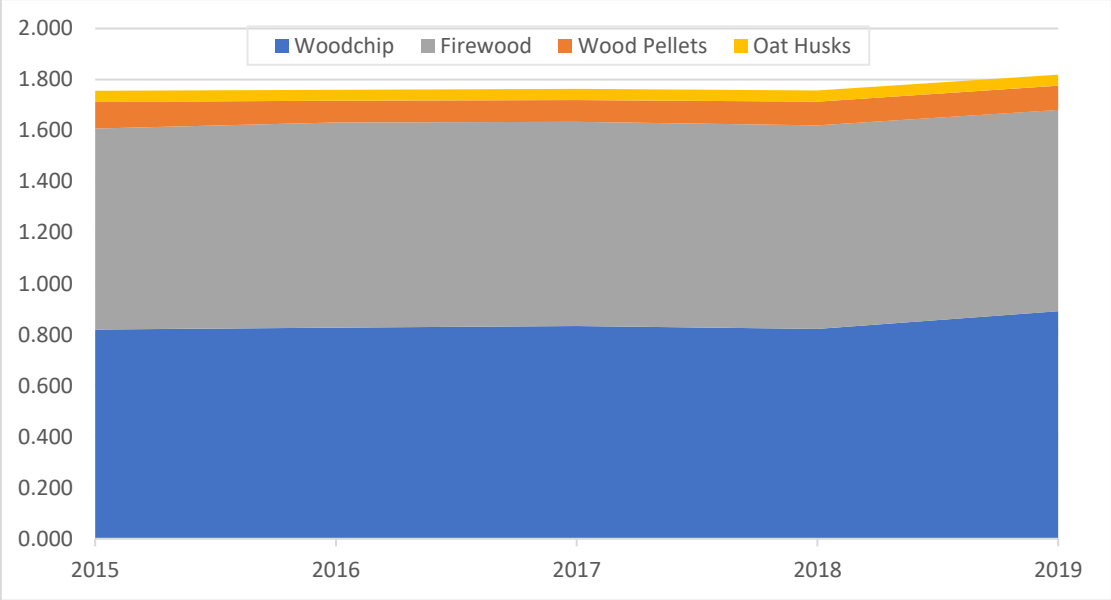


*Figure 19: Wood fuel use in Dunedin by type from 2015 to 2019FY.*

# 5. Coal

## Coal supplies in Dunedin

There are no active coal mines in Dunedin. The closest mine is Kai Point Coal, which is located near Kaitangata. Personal communications with retailers suggest that the majority of coal supplied within the city is sourced from Kai Point Coal (Otago), Ohai Coal (Southland) and New Vale Coal (Southland). Some coal may also have been sourced from West Coast mines[25].

Data could not be obtained for the amount of coal supplied to Dunedin-based customers, so an approximation has been calculated based on coal demand within the city.

## Coal demand in Dunedin

### Organisational demand

Data was sourced from the EECA boiler list, Ahika and BANZ to create a database of known coal boilers within Dunedin. Where applicable, updated information on boiler sizes and fuel demands has been used to update the boiler database.

47 boilers were identified for which no specific coal consumption data could be obtained. 39 of these boilers are used for space heating of primary and secondary schools and it is estimated that they consumed 0.039 PJ of coal during the 2019FY. The remaining eight boilers were used for heating rest homes, food processing and in the chemical industry. It was calculated that these boilers consumed 0.183 PJ of coal during the 2019FY.

Exact coal consumption data was provided by several organisations and subsequently these boilers were removed from the database to improve accuracy and prevent double counting.

The Dunedin Energy Centre is the only district heating scheme in Dunedin and provided steam for process and space heating to several organisations, including the University of Otago, the Southern District Health Board and Cadbury (now closed). Dunedin Energy

[25] See https://www.nzpam.govt.nz/our-industry/nz-minerals/minerals-data/coal/operating-mines/ for a description of all New Zealand coal mines.

Centre historically only burned coal in its four boilers. However, one of the four boilers was converted in 2018 to operate with woodchip fuel. It was calculated that 0.275 PJ of coal was consumed at this site during the 2019FY, a decrease of 31% compared to the 2018FY of 0.398 PJ which was likely due to the closure of the Cadbury factory and the conversion of one of the four coal fired boilers at the Dunedin Energy Centre to biomass.

The University of Otago also uses coal at a number of its sites. During the 2019FY, the University consumed 0.016 PJ of coal. This is a 9% reduction from the 2018FY. No coal was consumed at any of the University-affiliated residential colleges.

**Approximately 0.512 PJ of coal was consumed in Dunedin boilers during the 2019FY. This is a 19.5% reduction on the 2018FY.**

## Residential demand

The 2018 census shows that coal burners are used as one of the main sources of heating in 4.2% of Dunedin households. A linear regression of census data from 2001, 2006, 2013 and 2018 was used to predict that approximately 1,140 Dunedin households used coal as a heating fuel in the 2019FY.

The People's Panel survey indicated that households which use coal would consume an average of 353 kg per year.

**It is estimated that Dunedin residents consumed 0.016 PJ of coal in the 2019FY. This is a reduction of 25% on the 2018FY.**


*Figure 20: Comparison of organisational and residential coal use in Dunedin during the 2019FY.*

**Total coal consumption in Dunedin is estimated to be 0.528 PJ for the 2019FY. This is a 20.2% reduction on the 2018FY.**

# 6. Sulphur

Ravensdown Fertiliser Co-operative Limited combusts elemental sulphur in the boiler at its plant in Ravensbourne. The combustion products are processed into acid for use in the manufacturing of fertiliser at this plant.

The combustion of sulphur produces heat and steam as co-products which are used for electricity generation and industrial heat. Ravensdown Ltd generated 690 MWh of electricity in the 2019FY. This electricity is included in the electricity section of this report.

**Based on previous studies, it is estimated that around 0.246 PJ of sulphur would have been consumed by Ravensdown Ltd during the 2019FY.**

# 7. Greenhouse Gas Emissions

Emissions factors were used to determine the greenhouse gas (GHG) emissions in terms of the energy use (kg $CO_2$-e/unit), as follows:

- Petrol (litre): 2.43
- Diesel (litre): 2.72
- LPG (kg): 3.03
- Electricity (kWh): 0.1038
- Wood – residential (kg): 0.067
- Wood – industrial (kg): 0.015
- Coal – default (kg): 1.95

These conversions have been updated from previous Dunedin Energy Studies to the most recent official figures[26]. Personal communications with the University of Otago Energy Co-ordinator and retailers of pellet fires suggests that the government emissions factors for the combustion of wood products may not be accurate for Dunedin applications. This is due to assumptions made about the composition and moisture content of the wood products used. Overall emissions calculations have been improved in the current and previous reports by updating the emissions factors with assistance of the University of Otago Energy Coordinator and splitting residential and industrial wood consumption. **Further work is still required to validate the emissions factors which are applied to these categories.**

The official emissions factor for electricity production in New Zealand has not been updated since 2013. An electricity emissions factor (including distribution losses) for the 2018FY was therefore calculated based on Ministry of Business, Innovation and Employment (MBIE) and Ministry for the Environment (MfE) datasets[27]. The increased electricity emissions factor is due to a 2.3% net reduction in renewable generation, which required an 18% increase in non-renewable generation to meet demand. The

[26] Emissions factors were based on those supplied in the Ministry for the Environment's *Guidance for Voluntary Greenhouse Gas Reporting – 2016:* *http://www.mfe.govt.nz/sites/default/files/media/Climate%20Change/2016-guidance-for-voluntary-corporate-greenhouse-gas-reporting.pdf*

[27] Electricity emissions factors are calculated from the MfE *Summary of Emissions Factors for the Guidance for Voluntary Corporate Greenhouse Gas Reporting - 2015* , MBIE datasets of New Zealand's electricity generation for the 2018FY (https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/electricity-statistics/) and MBIE energy balance tables (https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-balances/)

increase in non-renewable generation was comprised of 60% from natural gas and 40% from coal.

The conversion of sulphur to sulphuric acid at Ravensdown Ltd's Dunedin factory does not produce any carbon dioxide emissions, although fluoride and sulphur dioxide emissions are released during this process. The exact quantities of these are unknown and are subsequently not included in the following greenhouse gas inventory for the city. **Further research is required in this area.**

*Table 2: $CO_2$-equivalent emissions from energy use in Dunedin during the 2019FY*

| Fuel | Total energy (PJ) | Total CO2-e (kt) | Share of emissions | Share of energy inputs |
|---|---|---|---|---|
| Petrol | 2.694 | 186.64 | 26.8% | 20% |
| Diesel | 4.888 | 345.79 | 49.7% | 36% |
| LPG | 0.361 | 22.15 | 3.2% | 3% |
| Electricity | 3.185 | 91.83 | 13.2% | 23% |
| Wood - Residential | 0.824 | 5.52 | 0.8% | 6% |
| Wood - Industrial | 0.928 | 1.41 | 0.2% | 7% |
| Coal | 0.528 | 42.33 | 6.1% | 4% |
| | | | | |
| Total | 13.65 | 695.67 | | |

**A total of 696 kt of $CO_2$-equivalent were emitted from Dunedin-based energy consumption during the 2019FY. This is an overall increase in emissions of 3% from 2018FY and is predominantly driven by the 12% increase in diesel consumption within the city.**

Petrol and diesel make up 56% of Dunedin's energy supply but contribute 77% to the city's energy greenhouse gas emissions. Wood based biofuels however, make up 13% of Dunedin's energy supply but only contribute just over 1% of the total emissions.

# 8. National Comparisons

Comparisons were made with two national datasets: the energy balance tables produced by MBIE[28], and the energy end use database produced by EECA[29]. These datasets have been converted to a per capita basis, based on the latest New Zealand Statistics estimates for the relevant area's population.

## Energy Balance Tables

This study is compared with national data for the 2018 calendar year. The compared periods are six months out of alignment but this was the most recent data available and should provide a reasonable approximation. This comparison is displayed in Table 3.

It should be noted that the national figures cover a much more varied set of activities than occur in Dunedin. For this reason, not all fuels are available and used in the same way in Dunedin as they may be in the rest of New Zealand. Specific examples are noted below.

*Table 3: Comparison of per capita energy use of Dunedin residents in the 2019FY to national averages from 2018.*

| Fuel | Dunedin Energy Study (MJ/person) | National Energy Balance (MJ/person) | Dunedin Proportion of National Average |
|---|---|---|---|
| Petrol | 20,459 | 23,021 | 89% |
| Diesel | 37,116 | 28,220 | 132% |
| LPG | 2,738 | 1,770 | 155% |
| LPG + NG | 2,738 | 16,812 | 16% |
| Electricity | 24,183 | 29,052 | 83% |
| Wood | 13,306 | 11,511 | 111% |
| Coal | 4,006 | 4,976 | 81% |

Dunedin uses 11% less petrol and 32% more diesel per capita than the national per capita average.

LPG usage is much more prevalent in the South Island due to the lack of a reticulated natural gas network such as that which services a large proportion of the North Island.

[28] Source: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-statistics/energy-balances/
[29] Source: https://www.eeca.govt.nz/resources-and-tools/tools/energy-end-use-database/

No natural gas is distributed in the South Island. This helps explain why Dunedin consumes 55% more LPG than the national average, which is widely used for cooking and water/space heating. If natural gas (NG) is included in the national figures, Dunedin uses 84% less gas than the national average. Natural gas is widely used for large scale industrial processes such as electricity generation and milk drying, none of which occur on Dunedin's LPG network.

Dunedin consumed 11% more wood energy than the national average. The consumption of wood in Dunedin is much more comparable to national averages than in previous studies due to the improved data on wood fuels in the current report. Dunedin also has very good access to wood fuels compared to many other New Zealand centres. It is possible that the greater wood consumption may be offsetting some of the electrical load used for space heating in other regions.

During the 2019FY, Dunedin used 17% less electricity than the national average and 19% less coal. The quantity of coal consumed in Dunedin is largely based on calculated values from historic boiler datasets and census data. This represents a significant uncertainty as the upgrading of boilers and variations in their annual utilisation are constantly occurring, as well as the linear interpolation of census data. The largest use of coal in Dunedin is for district heating. Nationally, coal is largely used for industrial processes such as steel manufacturing, electricity generation and milk drying. Because Dunedin does not have any of these large coal based industrial processes, it is not surprising that per capita consumption should be slightly lower than the national average.

During the 2019FY, 33.4% of Dunedin's energy was from renewable sources. This is an increase of one percentage point from the previous year and compares to a national average of 39.9%.

## Energy End Use Database

EECA's energy end use database provides estimates of the energy used in various New Zealand regions. The most recent version of this database for Otago is from 2012. This is compared to the findings from the current study in Table 4.

Table 4: *Comparison of per capita energy use of Dunedin residents in the 2018FY to Otago wide averages from 2012.*

| Fuel | Dunedin Energy Study (MJ/person) | 2012 Otago End Use Energy (MJ/person) | Dunedin Proportion of Otago Average |
|---|---|---|---|
| Petrol | 20,459 | 30,636 | 67% |
| Diesel | 37,116 | 27,690 | 134% |
| LPG | 2,738 | 7,275 | 38% |

| | | | |
|---|---|---|---|
| Electricity | 24,183 | 23,342 | 104% |
| Wood | 13,306 | 7,456 | 178% |
| Coal | 4,006 | 5,293 | 76% |

Table 4 suggests:

- Dunedin used 33% less petrol and 62% less LPG than the regional average.
- Dunedin used 34% more diesel than the regional average.
- Dunedin's electricity use is similar to the regional average.
- Dunedin used approximately 80% more wood fuels than the regional average.
- Dunedin used 24% less coal than the regional average.

The large variation between Dunedin's LPG use and the regional average is supported by the discrepancy found in this study between Dunedin's LPG supply and demand.

## Greenhouse gas emissions

The EECA energy end use database also provides estimates of GHG emissions associated with reported energy use. The most recent version of this database at the national level is from 2016. This is compared to the findings from the current study on a per capita basis in Table 5.

*Table 5: Comparison of per capita energy emissions of Dunedin residents in the 2019FY to national averages from 2016.*

| Fuel | Dunedin Energy Study (t $CO_2$-e/person) | National End Use Emissions (t $CO_2$-e/person) | Dunedin Proportion of NZ Average |
|---|---|---|---|
| Petrol | 1.417 | 1.600 | 89% |
| Diesel | 2.626 | 1.821 | 144% |
| LPG | 0.168 | 0.104 | 162% |
| LPG + NG | 0.168 | 1.008 | 17% |
| Electricity | 0.697 | 0.830 | 84% |
| Wood | 0.053 | 0.020 | 265% |
| Coal | 0.321 | 0.440 | 73% |

The per capita emissions are in proportion to the amount of each of the different types of fuel used in Dunedin and nationally (Table 3).

Emission factors and calorific values for wood fuels have been updated in the current study and represent more accurate values than in previous reports. However, it has been raised by several stakeholders that the official emissions factors for wood fuels in particular are inaccurate for the real-world application in Dunedin.

# 9. Trends

In this section we track some of the high-level trends that are now starting to become evident from the annual Dunedin Energy Studies. We use the 2016-2019 data, with some earlier data adjusted (as noted in this report) as a result of improved methods.

**Dunedin's annual energy consumption has increased year on year, from 11.61PJ in 2016 to 13.65PJ in 2019.**

Population growth and GDP growth can both be drivers of increased consumption.

Table 6 shows that energy use has been growing faster than population. Energy consumption per capita has increased year by year (Row 3). This could mean that individuals are on average using more energy in their daily lives, or the difference could be wholly or partly from economic growth in the city.

Table 6: Energy trends compared to population and GDP trends.

| Year | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| Demand (PJ) | 11.61 | 12.77 | 13.41 | 13.65 |
| Population | 126,900 | 128,650 | 130,500 | 131,700 |
| Energy demand per capita (MWh) | 25.39 | 27.57 | 28.54 | 28.79 |
| GDP | $5,654m | $5,810m | $5,968m | $6,162m |
| Energy demand per $m GDP (MWh) | 570 | 610 | 624 | 615 |

**Energy consumption has increased faster over 2016-2019 than the population has grown. Averaged over the population, consumption has increased from 25.39 MWh per capita in 2016 to 28.79 MWh per capita in 2019** (Table 6, Row 3).

**Dunedin also has had a trend of using more energy per unit of GDP. The ratio of energy consumption per $million GDP increased from 570MWh per $million GDP, to 624 MWh per $million GDP in 2018, easing back slightly to 615MWh in 2019** (Row 5, Table 6). **The figures suggest that the Dunedin economy has an overall trend of becoming less efficient (using more energy per unit of GDP)** (Figure 21).

Without a lot more work it is not possible to untangle whether Dunedin's increased energy use is primarily driven by more energy use per household or less efficient use of the energy that drives the local economy. Regardless, these are both trends that need to be turned around if Dunedin is to achieve its goals for a low-carbon future.

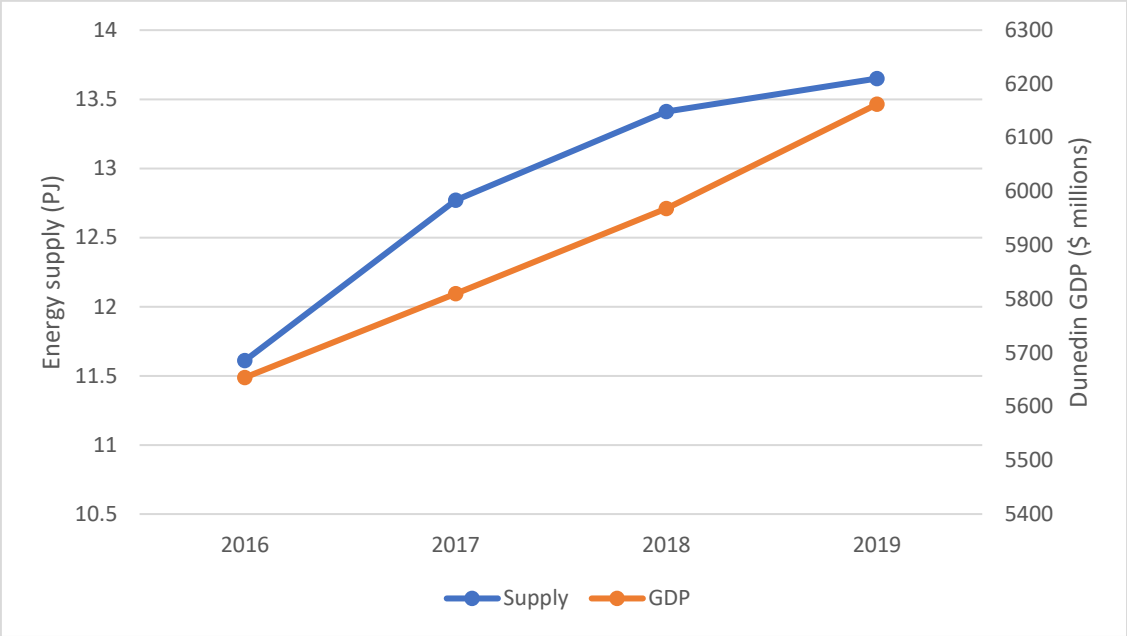


*Figure 21: Comparison of total energy demand and Dunedin GDP.*

**There has been an increase in the proportion of non-renewable fuels from 63% in 2016 to 67% in 2019.** Trends in energy supplies are shown in Table 7 & Figure 22.

In summary:

- Diesel supplies have grown significantly with a 26% increase since 2017
- Biomass and LPG supplies have increased every year since 2016
- Electricity and petrol supplies have been relatively constant over 2017-2019
- Coal supplies have decreased slightly since 2017

Table 7: Energy supply broken down into fuel types (PJ) by year

| Year | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| Petrol | 2.59 | 2.65 | 2.76 | 2.69 |
| Diesel | 4.08 | 3.89 | 4.36 | 4.89 |
| LPG | 0.46 | 0.58 | 0.67 | 0.73 |
| Electricity | 3.35 | 3.15 | 3.17 | 3.18 |
| Biomass | 0.21 | 0.42 | 0.45 | 0.51 |
| Coal | 0.63 | 0.67 | 0.65 | 0.53 |

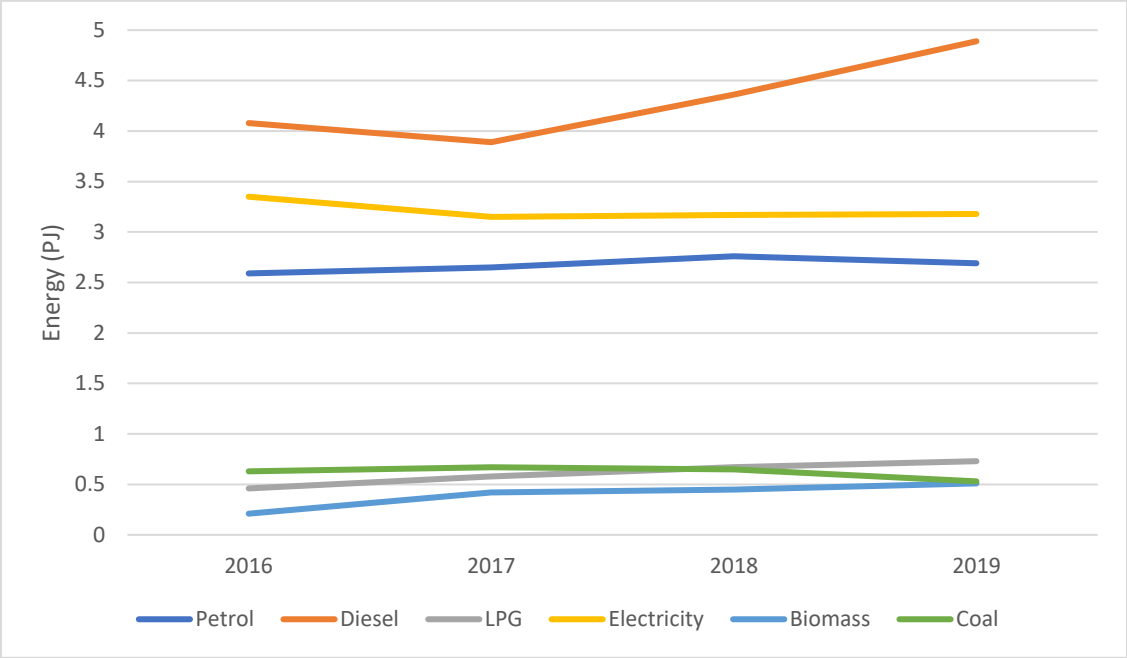


*Figure 22: Energy supply broken down into fuel types.*

**As a result of these trends, energy-related greenhouse gas emissions have been growing year on year, from 616 kt CO2-e in 2016 to 713 kt CO2-e in 2019 (Table 8 and Figure 23). This is a 15.7% increase in four years.**

Table 8: Energy-related GHG emissions, by years

| Year | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| GHG emissions (kt CO2-e) | 616 | 633 | 672 | 713 |

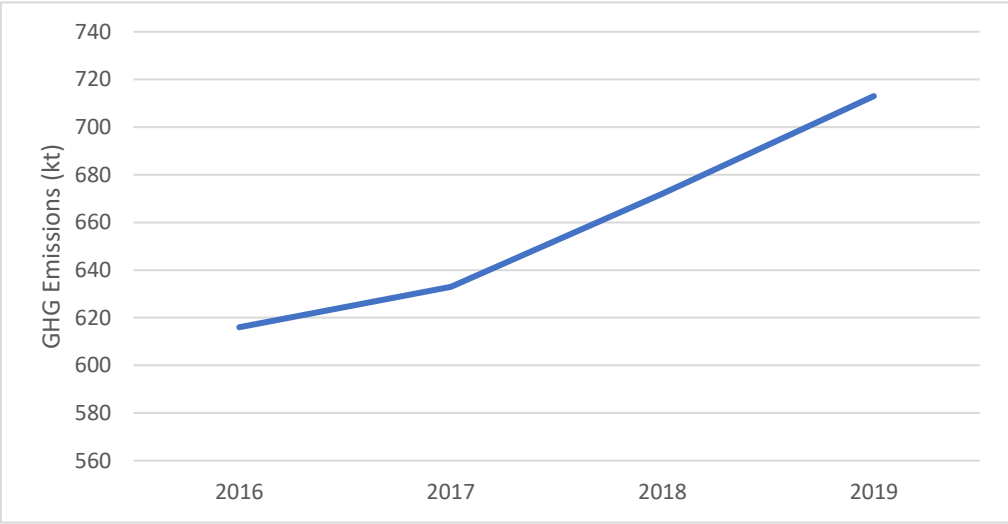


*Figure 23: Energy-related GHG emissions, by years*

# 10. Conclusions

This study has attempted to gather data on all energy inputs into Dunedin. This has been used to provide a snapshot of energy use in the city and to identify trends by comparing to previous Dunedin Energy Studies.

During the 2019 financial year (1st July 2018 to 30th June 2019) a total of 13.65 PJ of energy was used within Dunedin. This is an increase of 2% from the 2018FY and predominately driven by the 12% increase in diesel consumption within the city (based on a 'proportion of rates' method of allocation).

56% of the city's total energy consumption was from petrol and diesel, 3% from LPG, 23% from electricity, 13% from biomass, 4% from coal and 2% from sulphur. These proportions are similar to previous studies, with the major variations being a 6% reduction in LPG demand and decrease in coal demand by 21%, but a 2% decrease in petrol and a 12% increase in diesel consumption.

33.1% (4.52 PJ) of Dunedin's total energy consumption during the 2019FY was from renewable sources. This is 4.0% more than the 2018FY renewable proportion for Dunedin.

When compared to previous years (with previous years' figures adjusted where necessary to align with newer and more accurate methodologies) it is clear that **Dunedin's energy trends are largely heading in the wrong direction**. While Dunedin City Council's policies are targeting more efficient use of energy, more renewable energy and reduced energy-related GHGs, we have found:

- **Dunedin's annual energy consumption has increased year on year**
- **Energy consumption per capita has increased year on year**
- **Energy consumption per unit of GDP has increased 2016-2018 (i.e. less efficient use of energy), easing back slightly in 2019.**
- **There has been an increase in the proportion of non-renewable fuels from 63% in 2016 to 67% in 2019.**
- **Energy-related greenhouse gas emissions have been growing year on year, with a 15.7% increase over the past four years.**

## Implications for Dunedin's energy and carbon emissions targets

Dunedin City's main goals relating to energy in its Energy Plan, Economic Development Strategy and Environment Strategy are:

- increasing energy efficiency

- increasing proportion of renewable energy
- greater local energy security
- growing use of biomass energy
- decreasing energy-related greenhouse gas emissions

## Positive trends in relation to these goals

**Coal use down:** Since the commencement of this Dunedin Energy Study, coal use has trended down. In the last year alone, coal demand has decreased 21%. As one of the most carbon intensive fuels used, this decrease has in turn lead to a decrease in associated GHG emissions from this fuel type.

**Petrol use down:** While petrol consumption increased slightly in previous years of this study, it decreased by 2% in the 2019FY.

**Solar generation up:** Photovoltaic installations in Dunedin grew by 17% (50 installations) over the 2019FY. The general trend has seen an average increase of 62 installations per annum since the 2013FY.

**Electric vehicles up:** The EV fleet in Dunedin has steadily increased every year since 2015, with 308 new registrations in the 2019 calendar year.

## Negative trends in relation to these goals

**Energy use increasing:** Total energy consumption has increased year on year, with an overall increase of 17.6% since 2016. It increased by 2% between the 2018 and 2019 FYs.

**Diesel use up:** There was a 12.1% increase in the total diesel consumed in Dunedin compared to the 2018FY. Diesel use made up 50% of Dunedin's energy-related greenhouse gas emissions. This trend of increasing diesel use has continued since the 2016 FY.

**LPG use up:** LPG use has almost doubled, from 0.46PJ in 2016FY to 0.73PJ in 2019 FY.

**Biomass use not increasing:** Dunedin's use of biomass has remained relatively constant over 2016-2019.

**Less efficient use of energy**: Energy consumption per capita has increased year on year. Energy consumption per unit of GDP increased 2016-2018, easing back slightly in 2019.

**Higher proportion of fossil fuels:** There has been an increase in the proportion of non-renewable fuels from 63% in 2016 to 67% in 2019.

**More energy-related greenhouse gas emissions:** These have been growing year on year, with a 15.7% increase over the past four years.

**More emissions intensity:** While the 2019FY energy consumption increased by 1.9% from the 2018FY, the total greenhouse gas emissions from this energy consumption increased by 2.7%, which means that Dunedin's overall energy portfolio was more emissions intensive during the 2019FY compared to the 2018FY, which was in turn more emissions intensive than the 2017FY. These increases are primarily the result of an overall increase in fossil fuel consumption, mainly diesel. Variations in national electricity generation methods will also affect these proportions.

**Heavy reliance on energy imports:** 84% of energy used in Dunedin was sourced from outside the city's boundaries. All transport fuels, LPG, coal and sulphur were imported from other regions of New Zealand or from overseas.

## Recommendations

The city is largely failing to achieve its energy-related aspirations. Although there are a few positive trends, these are of a minor scale and are heavily outweighed by negative trends.

DCC's energy and climate targets have been in place for a number of years and yet key trends are heading in the opposite direction. Clearly, policies are not working.

There is an urgent need for a re-think of how the city council can turn these negative trends around. This means taking these goals seriously in the council's own day to day decision-making and developing collaborations for change with other key actors in the region.

Actions ultimately need to:
- make it easier for businesses and households to adopt energy efficiency, renewable energy and low-carbon transport
- continue to improve public and active transport infrastructure and its use by the public and businesses
- support continued uptake of EVs and other electric mobility (e.g. electric bikes)
- support reduction in coal use by institutions, businesses and households
- support households to improve insulation and clean heating
- make better use of Dunedin's forest resources for biomass
- discover why diesel and LPG use are increasing, and in what sectors this use is occurring, and target these sectors for action

## Developments and Limitations

Based on the insights gained through this study, several data collection methodologies were refined to improve the accuracy of this report:

- New and improved data sources have improved the accuracy of wood and LPG supplies in Dunedin. However, it has exposed an error in wood data supplied and increased uncertainty in this area.
- The database detailing Dunedin-based boilers and their fuel types was updated.
- Updated census data was used to increase the confidence in wood, LPG and coal demand in Dunedin.
- Diesel, petrol and LPG data is allocated to Dunedin on the basis of relative population in the Coastal Otago area. This has inherent limitations on the accuracy of the findings in relation to these fuels, but is consistent with the way in which these taxes are allocated across Dunedin, Clutha and Waitaki councils.

## Future Research

Although several improvements have been made over previous studies, there still remain some data gaps and uncertainties that require further research. These are summarised below:

- Further work is needed to better understand where diesel is being consumed in Dunedin, including for non-transport purposes such as running machinery, on-farm use and for home heating.
- Additional research is needed to further investigate the uses of LPG, both within the city limits and in other areas that source LPG which is unloaded in Dunedin, and to reduce the discrepancies between supply and calculated demand.
- Further work is required to update the emissions factors for wood fuels in a Dunedin context for both residential and organisational uses.
- Obtaining data from coal suppliers in Dunedin would greatly improve the accuracy of this aspect of the study.
- A statistically robust survey of household wood and coal use would be helpful to get more certainty around consumption and trends.

Additionally, the government allocation of fuel tax to the 'Coastal Otago' area, which then has to be pro rata allocated to three modern local authority areas, brings uncertainties to the quality of the data on petrol and diesel supplies. DCC may wish to follow this question up with the relevant government agencies.

With the methodology refining annually, and data sources more reliable, the accuracy of the findings presented in this report are constantly improving. The continuation of this study over 5 years has allowed us to start to identify trends with some degree of certainty. Repeated annual studies will allow the clarification of any trends in energy generation, consumption and subsequent greenhouse gas emissions. This will provide a basis for identifying areas requiring action and will help track the effectiveness of interventions.